Usiakimi Igbaseimokumo

Brain CT Scans in Clinical Practice

Second Edition

Springer

In Clinical Practice

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Foreword

Interpretation of the emergency CT brain scan is a visual art. Comparison is made between the image in front of you and a reference image. For the experienced person this reference image is imprinted in the mind; therefore comparison is quick. For the beginner you can either carry several examples of every possible appearance of normal and abnormal scans to compare with or read this book! This book contains a few proven ways of quickly learning to interpret a brain CT scan, irrespective of your previous experience.

The radiologist's experience is related to the number of hours he or she has spent looking at CT scans. The radiologist conveys his evaluation of the CT scan in words that often come in a particular sequence and combination. This book is about helping you to rapidly understand and confidently use the same language used by the radiologist.

The difference is that whereas the radiologist aims for perfection, you aim for functionality. For instance, it will be acceptable and clinically safe if an intern physician looks at the brain CT scan in Fig. 1 and can make a judgement of the urgent action required like ABCs (***A***irway, ***B***reathing and ***C***irculation with c-***s***pine) and *call a neurosurgeon* ***immediately.*** This is lifesaving and efficient without the need for a long list of differential diagnoses before deciding on this action. Since the first edition, image presentation and storage has moved from films to digital format. The author has seamlessly introduced this new platform in explaining the concepts of interpreting the emergency brain CT scan. Therefore, the skill to act decisively about the CT scan in

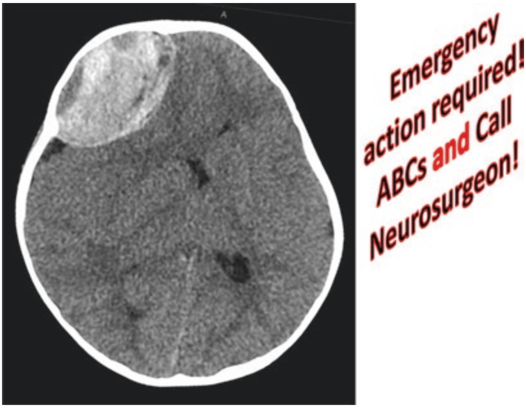

FIGURE 1. Epidural hematoma! Emergency action required! ABCs and call neurosurgeon!

front of you can be acquired in a very short time. And the author has reduced that time to a few hours using this book!

Lubbock, TX, USA Roy Jacob, M.D., DABR

Preface

> An illustrated guide for ER physicians, trauma surgeons, primary care physicians, residents, medical students, nurses and other care givers

Across emergency rooms all over the world, thousands of patients are referred for brain CT scans daily. A radiologist often has to interpret the scan or a consultation has to be made to a neurosurgeon to review the scan. Most of this happens late at night and is a significant source of discontent. Thus, having frontline physicians to be proficient in interpreting the emergency brain CT scan improves the efficiency of the whole pathway of care and is potentially lifesaving as time is of the essence for many patients with severe brain injury or stroke.

Underlying all of the above and the primary reason for writing this book is that the skill required to determine *an immediate life-threatening abnormality* in a brain CT scan is so basic and can be learned in a short time by people of various backgrounds and certainly by all physicians. Indeed, 'the emergency head CT scan is comparable to an electrocardiogram in usefulness and most definitely as easy to learn'. This book is therefore written for caregivers the world over to demystify the emergency CT brain scan and to empower them to serve their patients better. It is obvious to me from the responses from people I have had opportunity to teach this subject that not only is there a desire to learn this basic skill but also people learn it quickly and wonder why it has not been presented so simply before.

It is to fulfil this need and to reach a wider number that I have put together these basic, proven steps in the interpreta-

tion of emergency brain CT scan for ER physicians, trauma surgeons, primary care physicians, nurses, medical students and other primary caregivers.

Since the first edition, the transition from X-ray film-based delivery of images to electronic delivery (e.g. PACS) has become more widespread. However, the examination of individual slices to reconstruct a three-dimensional image remains the cornerstone of CT imaging; hence this volume has retained the present format while recognizing the ability of the non-radiologist provider to manipulate individual images including enlarging and changing the window level. This technology is by no means universal and therefore not assumed in the description of images in this text.

Lubbock, TX, USA Usiakimi Igbaseimokumo

Acknowledgements

My heartiest gratitude goes to my wife Ebitimi and my kids Gesiye, Ilayefa and Binaere who volunteered the real cost in time to prepare this book. My eternal gratitude to the Isouns—Turner and Miriam—for spiritual, financial and intellectual support on this and every other project I ever embarked upon, thank you.

Always in my memory and fondly remembered forever will be Dr. Zuhair Taha whose passion for learning was a constant reminder to me to produce a volume like this. Unfortunately, Zuhair passed away before this work was completed. Adieu brother!

I would like to acknowledge Stacy Turpins for the original drawings and the framing of the illustrations.

To Roy Jacob, MD, DABR, I am most indebted for numerous images from his vast collection and for reviewing the manuscript and writing the foreword to this edition. And to Laszlo Nagy, MD, with whom I have had the benefit of discussing some of the interesting images and fascinating concepts; I am immensely grateful, because without him this second edition work would not have been possible.

My sincere gratitude to Medical Modeling for the prototype of a cover image.

Lastly despite their best thoughts and efforts, any error remains singularly mine and please e-mail me with any suggestions.

Contents

Chapter 1
Introduction to the Basics of Brain CT Scan

1.1 Three Basic Densities or Different Shades of Grey

The first secret is that we describe CT scan findings as '***densities';*** of which there are three common easily identifiable ones to learn. 'In general, the higher the density the whiter the appearance on the CT scan and the lower the density the darker the appearance on the brain CT scan.' The reference density (the one you compare with) is the brain, *usually* the largest component inside the skull. Anything of ***same*** *density* as brain is called **ISODENSE**, and it is characterized by a dull grayish white appearance (Fig. 1.1). ***Thus, the brain is the reference density***. Anything of ***higher*** density (whiter) than the brain is called **HYPERDENSE** and the skull is the best example of a hyperdense structure that is seen in a normal brain CT scan. The skull is easily identified as the thick complete white ring surrounding the brain. Similarly, anything of ***lower*** density (darker tone) than brain is described as **HYPODENSE**.

The cerebrospinal fluid (CSF) is the typical example of a hypodense structure in the brain CT scan (Fig. 1.1). Air is also hypodense and surrounds the regular outline of the skull in the CT scan, just as the air surrounds the head in life. Between the ***pitch-blackness*** of air and the ***grayish white*** appearance

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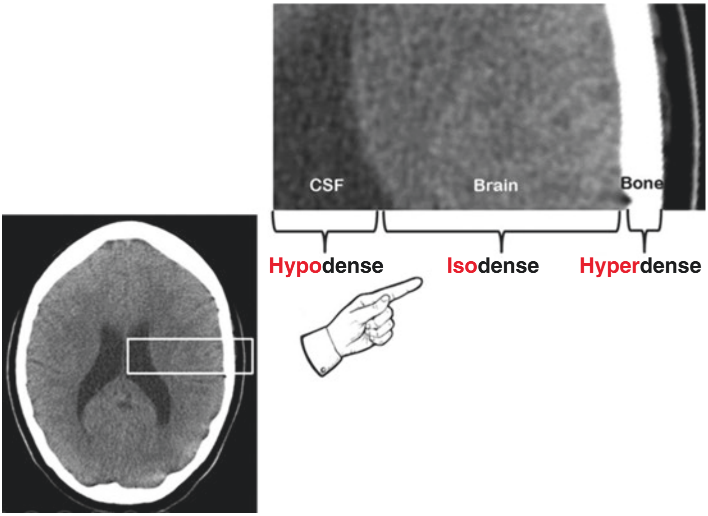


FIGURE 1.1 The basic densities of CT scan

of the brain, the cerebrospinal fluid presents a faint granular hypodense appearance which may vary slightly but is identified by its usual ***locations***. You will come to realize later that "appreciating the usual locations of CSF is the key to understanding brain pathology on CT scan" (Igbaseimokumo 2005). We will come back to this idea later but for now suffice it to say that the skull is literally white as this sheet of paper (Fig. 1.1) and is clearly identified as an oval white ring surrounding the brain. The brain is grayish white, and the CSF is dark and faintly granular on close inspection (but not as dark as air) and CSF has specific normal locations.

1.2 How to Identify an Abnormality on the CT Scan

Similar to the normal densities, abnormalities on the CT scan are also described simply as either *high density (**hyper**dense), low density (**hypo**dense) or same density (**iso**dense) as brain.*

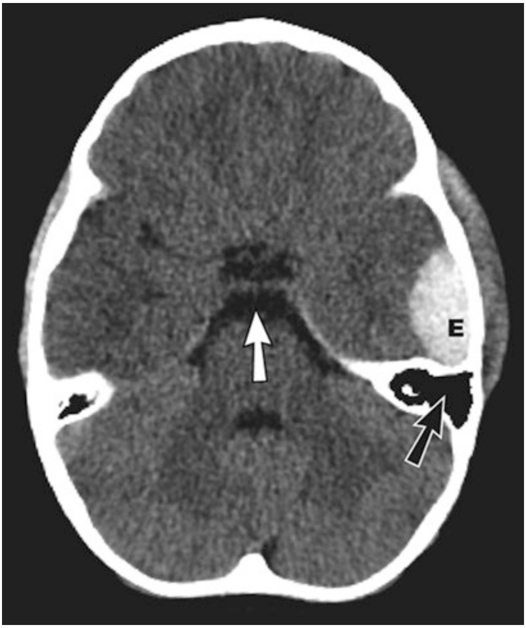


FIGURE 1.2 CT scan showing a left temporal acute epidural hematoma (E). Notice that the convex-lens shaped blood clot (E) has a density higher than brain but less than bone. Can you make out the boundary between the bone and the blood clot? You should linger here a little and 'absorb' the difference in density between the bone and the blood! Just behind the hematoma, the air in the mastoid (black arrow) is darker than the CSF in the center of the brain (white arrow). The CSF has a faint granular hue on close inspection which is absent in air

Therefore, what could a hyperdense (high density) appearance on a CT scan represent? This is perhaps the one most important fact you will get to learn about CT scans (Fig. 1.2). The answer is simple—***blood*** is the most common hyperdense abnormality found on a brain CT scan. ***If a hyperdense appearance is not in the right location for bone, then it must be blood until proven otherwise.*** Hence, the rule of thumb is that "***anything white in the CT scan is either blood or bone***."

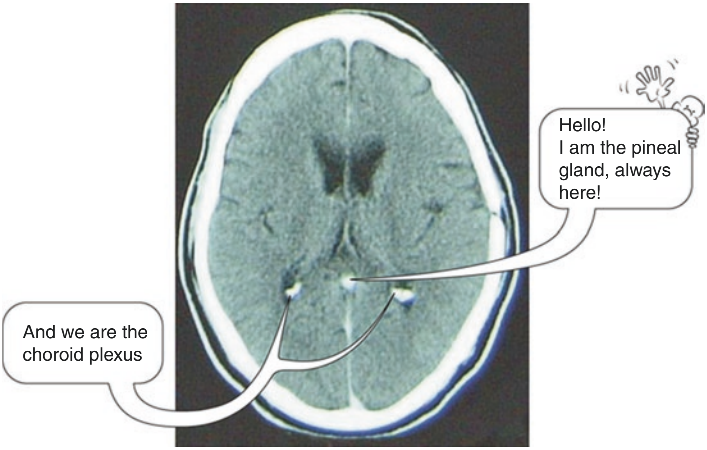


FIGURE 1.3 Brain CT scan showing pineal and choroids plexus calcifications

There are two common exceptions to the above rule. You might as well learn them now. The pineal gland is a little calcified speck in the middle of the CT scans of most adults. It is unmistakable after you see it a few times. Look, it is smiling at you in Fig. 1.3.

The second exception is calcified choroid plexus, which is located in the body of each lateral ventricle, lying indolently in the CSF like the Titanic at the bottom of the sea. They are so easily identified that you only need to see them once to remember (Fig. 1.3). Therefore, you can well assume at this stage that every other hyperdense lesion inside the brain is abnormal except for the choroid plexus in the ventricles and the pineal. *The important fact to take away is that most abnormalities will be hyperdense especially in the emergency setting*. Blood is the most common hyperdense lesion and I will later on describe what a calcified tumor looks like.

On the other hand, the common hypodense ***lesions*** seen on a brain CT scan are directly related to increased ***fluid*** in the brain as in edema from ischemic stroke (Chap. 3), tumors and infection (Chap. 5) and hydrocephalus (Chap. 4). We will come back to these later.

1.3 The Density of Blood Changes with Time!

Yes, the density of blood changes with time. Bleeding inside the head occurs from an injury such as a motor vehicle collision or a fall or burst blood vessels from high blood pressure. The blood is brightest on the first day of injury or bleeding and from then on, the density gradually fades. Therefore, in thinking about what you are seeing on the scan, it is important to remember how long after the injury or onset of symptoms before the scan was done. This is an important idea that we will come back to later in the book (Chap. 2) but an example of what happens to the blood with time is shown in Fig. 1.4. In describing changes over time, the word ACUTE simply means recent onset whereas CHRONIC means something that has lasted for a longer time.

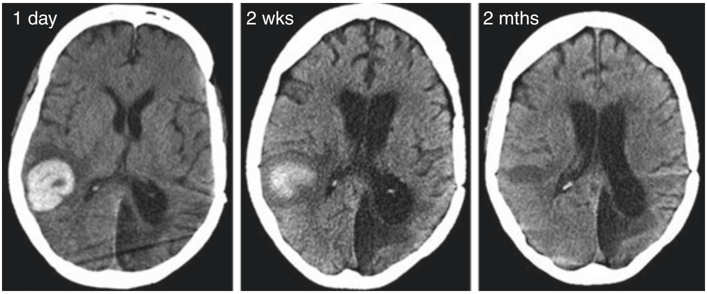


Figure 1.4 Note the change in the density of the blood from hyperdense (1 day) to hypodense with time (2 months)

1.4 Symmetry: Mirror Images, Like the Two Sides of Your Face

The next important fact will become apparent a lot quicker if you looked in a mirror (now!). Ok! If you don't have a mirror nearby, then try and recall the last time you looked in the mirror. For most of us: you had one ear, one eye, one nostril and *half a mouth* on either side of the face. In short, the left and right sides of your face look nearly identical! Similarly, the brain CT scan consists of two identical halves (mirror images). There is a dividing line which passes through the middle. Hence, if I give you one half of a normal CT scan (Fig. 1.5) you can actually recreate the other half, the mirror image!

FIGURE 1.5 Half of CT head (Can you sketch in the mirror image to show the choroids plexus and the ventricles and the skull?)

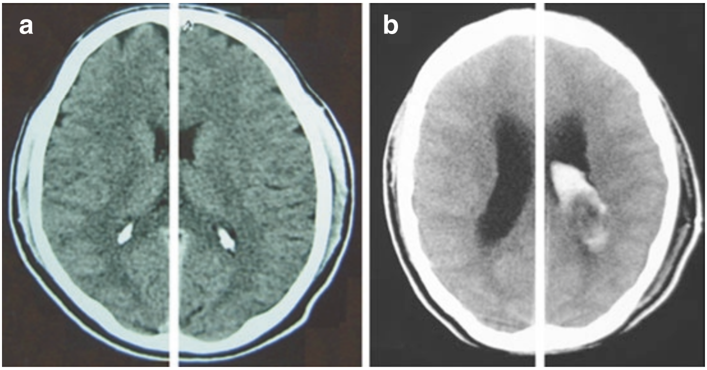


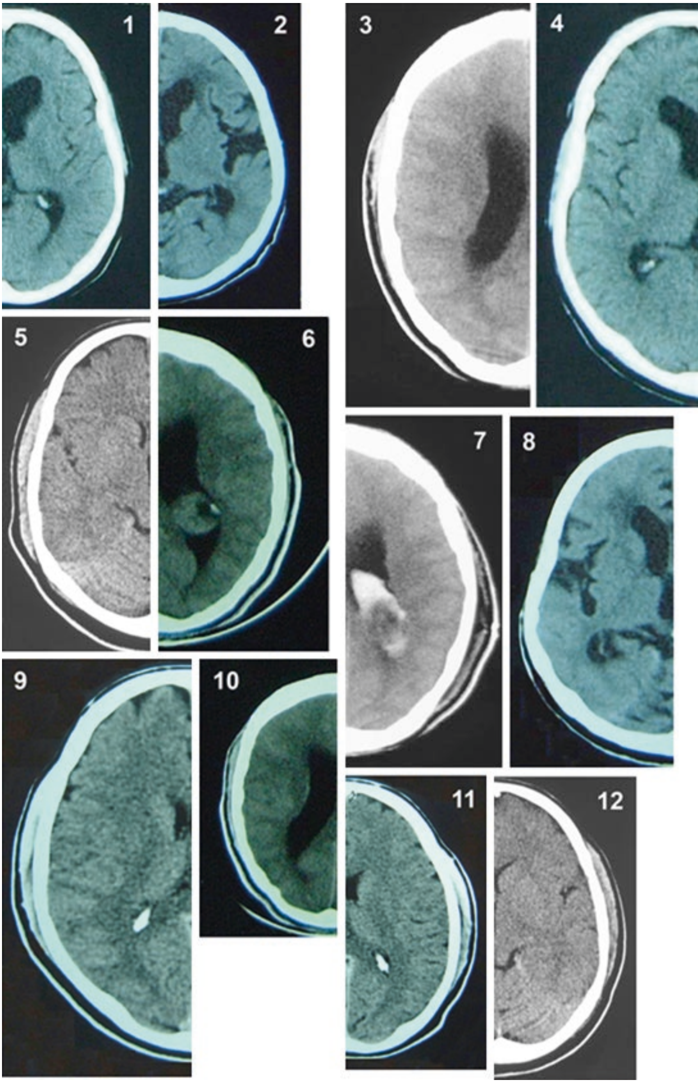
FIGURE 1.6 Brain CT scan with identical halves (**a** = normal scan) and an abnormal brain CT scan (**b**) showing blood clot in one half

The great news is this: ***even if you have never seen a CT scan before you can simply compare one half of the scan against the other half. If there are significant differences (for instance if the right and left halves are not the same) then the scan is abnormal*** (Fig. 1.6b). If the right and left are identical on every slice, then the image is said to be symmetrical and most *probably* normal (except in hydrocephalus where you can have symmetrical abnormality).

The following exercise will help drive home this very fundamental principle in learning to interpret brain CT scans. It includes normal and abnormal scans. ***Note that by convention the right side of the brain CT scan is on the left of the reader and it should be labeled as such (see*** Chap. 2***).***

Exercise 1 Can you pair-up the correct halves and mark which ones are abnormal?

Clue: One half of some of the pairs are enlarged. Focus on the pattern!



If you found the above exercise difficult: DON'T WORRY! Here is a simplified version showing an example of a normal scan with identical halves (mirror images) and one with a

significant abnormality on the opposite side. I hope you can say which side is abnormal in Fig. 1.6b!

1.5 Cerebrospinal Fluid (CSF) Spaces: 'The Compass for Brain CT Scan Interpretation'

The next important concept in understanding the brain CT scan is to identify the normal pattern of CSF spaces in the brain. The CSF spaces (low density) in Fig. 1.7a are large and easily identified. Examining the next two scans will show that the pattern is quite similar, but the spaces are smaller, yet all these films will pass as normal for different ages.

Just as the faces of mankind differ in appearance, so do the CSF patterns of our brains. In general, the brain on the left belongs to a very elderly person with lots of CSF spaces due to shrinkage of the brain (atrophy) and the one on the right belongs to a young adult. However, the similarity in the shape of the CSF spaces is apparent on close inspection. This teaches us where to look if the fluid spaces are not immediately obvious: for instance, you look where you ought to find 'CSF' and see *if* it has been replaced by blood as in subarachnoid hemorrhage or squeezed out by tumor. In the next section we will identify and name the different CSF spaces and also name the bony landmarks in the floor of the skull that relate to the CSF spaces.

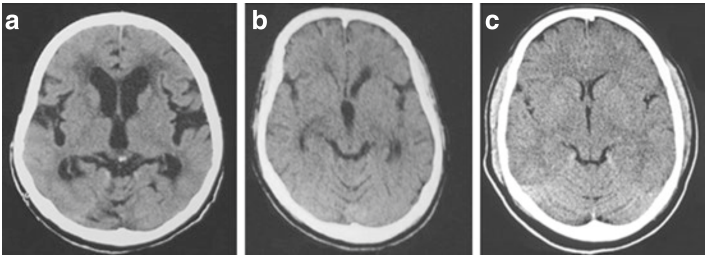


FIGURE 1.7 The pattern of CSF spaces in the brain in (**a**) elderly person (**b**) adult (**c**) younger person

1.6 Identifying Abnormalities in the CSF Spaces

The CSF spaces are the clue to identifying abnormalities on the brain CT scan. They could be filled with blood and appear hyperdense (Figs. 1.8 and 1.9) or the CSF could be squeezed out by swelling of the brain (Fig. 1.10) or by tumor (Fig. 1.15).

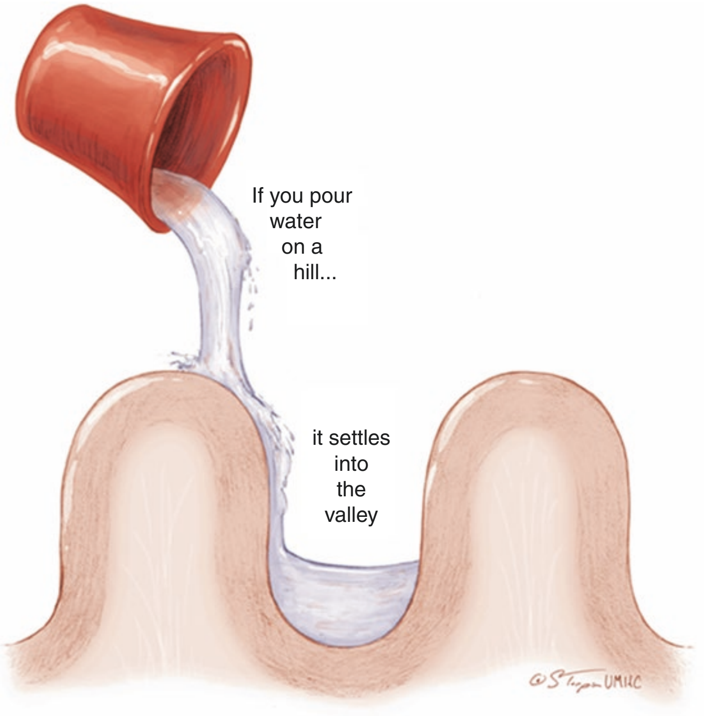


FIGURE 1.8 If you pour water or blood on a hill it will settle in the valley. In the brain the gyri are the hills and the sulci (which normally contain CSF) are the valleys, so the blood will settle in the SULCI displacing the CSF; therefore, instead of being dark the sulci turns white. This is a fundamental principle you need to understand in looking for subarachnoid hemorrhage in CT scan, as in the real example below (Fig. 1.9)

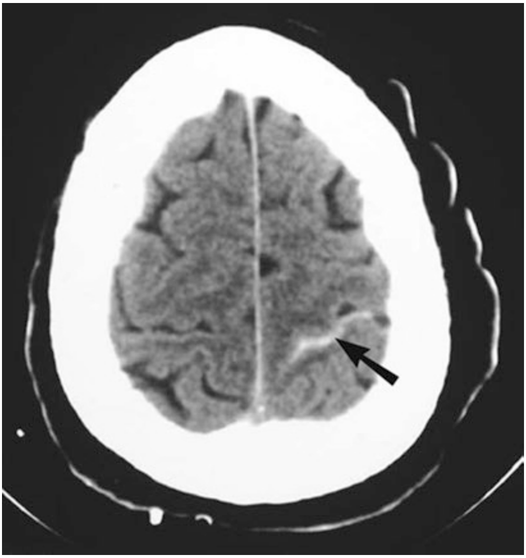


FIGURE 1.9 Brain CT scan of a 48 old year-old male following motor vehicle collision. It shows the hyperdense clot taking the place of CSF in the SULCUS (black arrow). You can also see normal sulci that appear dark. The straight white line in the middle is the falx cerebri and the blood in the sulcus is the white density inclined lazily at 45° to the falx cerebri (black arrow)

In either case knowing the usual location of the CSF spaces will help you to detect what is going on. We will examine a few large and ***readily*** identifiable ones and extend the same principles to less obvious cases.

1.7 Brain Swelling

The next important concept is this: whenever the brain swells, it means the gyri get larger and the sulci get smaller as illustrated below (Fig. 1.10):

In Fig. 1.12, the sulci and gyri may not be obvious either because of swelling or compactness as in most young people. However, it is very important to appreciate that the whole

brain surface is made of sulci and gyri which is easier to appreciate in Figs. 1.11, 1.13 and 1.20. All the gyri and sulci of the brain are named. Some of the CSF spaces are larger (big sulci) and more constant (present in every scan) and easily identified therefore they are used as the compass for

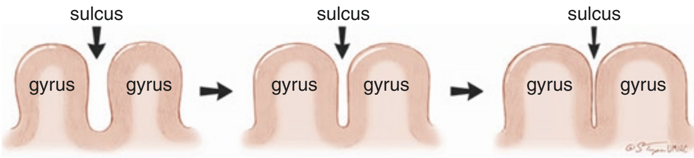


FIGURE 1.10 Schematic drawing showing how the sulci disappear as the gyri enlarge in brain swelling. In a real brain CT scan the appearance changes from the image in Figs. 1.11 to 1.12

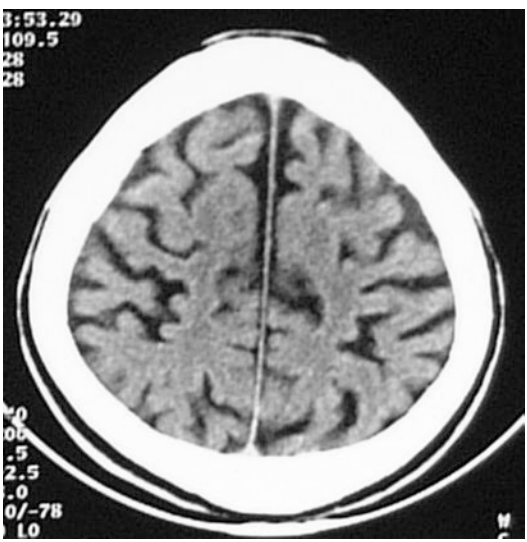


FIGURE 1.11 CT scan of the brain showing widely spaced CSF spaces. This and the next figure (Fig. 1.12) serve to illustrate the point that although some CT scan images appear simply as a granular mass as in Fig. 1.12, you should always bear in mind that it represents sulci and gyri on the surface of the brain as in this figure

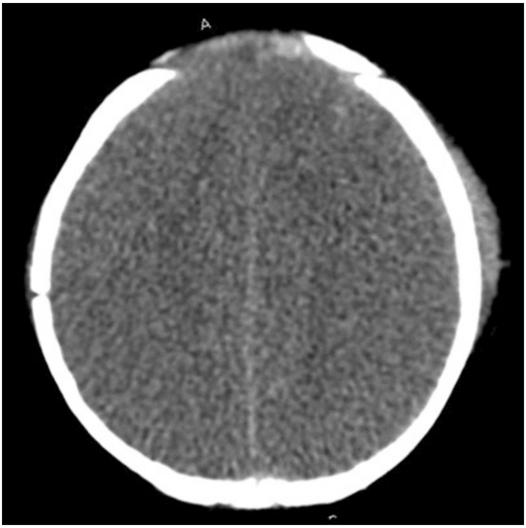


FIGURE 1.12 CT scan showing very tight almost absent spaces due to swelling. This and Fig. 1.11 serve to illustrate the point that although some CT scan images appear simply as a granular mass as in this figure, you should bear in mind that it always represents sulci and gyri on the surface of the brain as in Fig. 1.11

navigating the maze of sulci on the surface of the brain (Fig. 1.13). Can you name some of them?

Occasionally the presence of air (dark spots Fig. 1.14a) in the sulci allows us to appreciate easily that the homogenous looking appearance of the CT scan (Fig. 1.14b) actually consists of sulci and gyri.

1.8 Brain Tumors

The sulci may also be obliterated by expanding lesions within the brain such as a tumor or an abscess. In addition to mechanical compression of the sulci, associated swelling of the surrounding gyri from edema leads to the appearance of complete obliteration of the sulci as shown in Figs. 1.15 and 1.16.

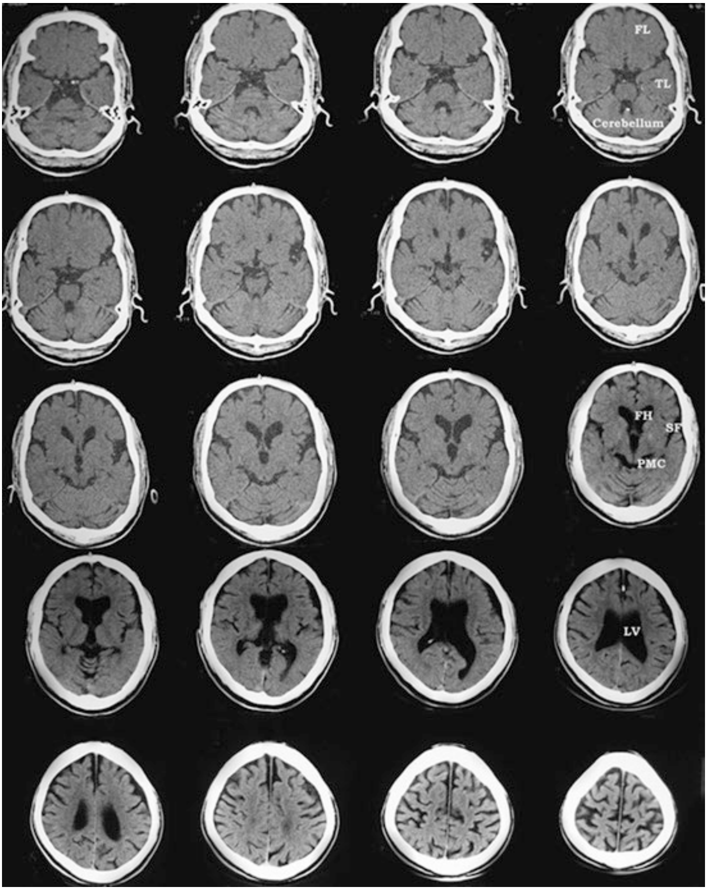


FIGURE 1.13 In the brain CT scan above the CSF pattern is more obvious and I have named a few landmark structures for your ready reference (*FL* frontal lobe, *TL* temporal lobe, *FH* frontal horn of lateral ventricle, *SF* Sylvian fissure, *PMC* perimesencephalic cistern, *LV* lateral ventricle)

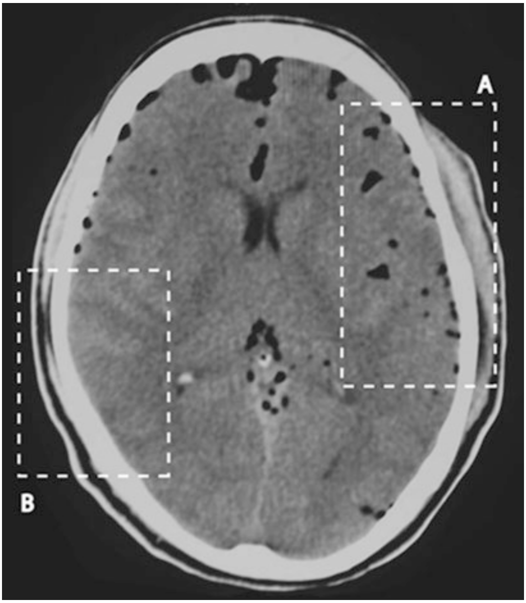


FIGURE 1.14 This 38-year-old male fell from a height at a construction site. He was comatose on admission with bilateral raccoon eyes. The brain in box B appears amorphous and granular while the brain in box A has the air (dark spots) outlining the sulci (A). It is important to emphasize that the air helps us to appreciate that the granular appearance in box B actually consists of gyri and sulci. ***Therefore, interpreting a CT scan does call for imagination of how the CT image relates to the three-dimensional human brain***

1.9 Extra Axial and Intra Axial Lesions

The type of lesions in Figs. 1.15 and 1.16 are called intra axial meaning it is inside the brain itself. On the other hand, a mass lesion that arises in the coverings of the brain like a meningioma (tumor of meninges: Figs. 1.17 and 1.18) which will immediately squash both gyri and sulci together are called an extra axial mass. The schematic drawing (Fig. 1.17) is a general illustration of what happens to the brain with an extra axial mass. Similarly, a blood clot on the surface of the brain

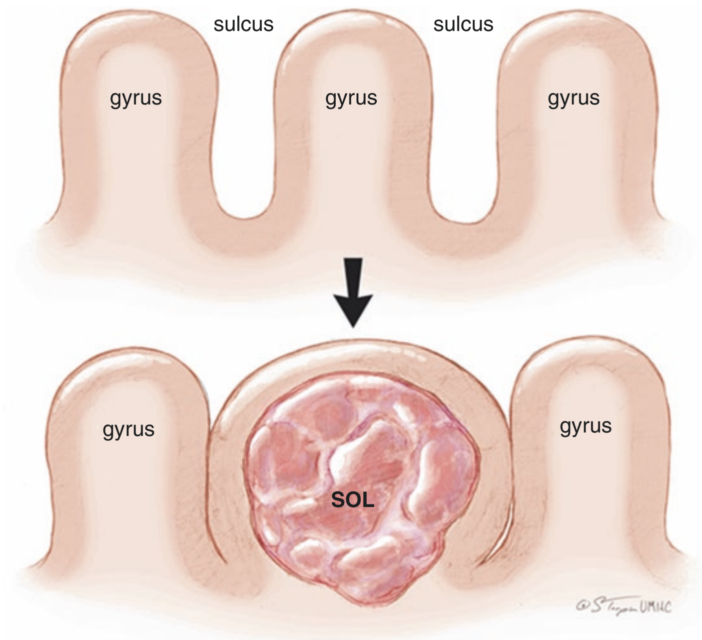


FIGURE 1.15 The term SOL stands for 'space occupying lesion'. This could be a tumor or abscess or blood clot which occurs in the center of the gyrus and expands outwards to squeeze the sulci

or over the membranes of the brain will also be an extra-axial lesion. Can you identify the abnormality in the CT scan in Fig. 1.17? ***And don't forget the right half of the (patient's) CT scan is on the left hand side of the reader!***

1.10 Basic Anatomy of the Brain Surface

To summarize; we have learnt that the brain surface consists of gyri and sulci and that the sulci are normally filled with CSF which gets replaced by blood or is squeezed out by swelling of the brain from edema or expanding masses (Figs. 1.15, 1.16, 1.17, and 1.18). Don't worry if you don't know

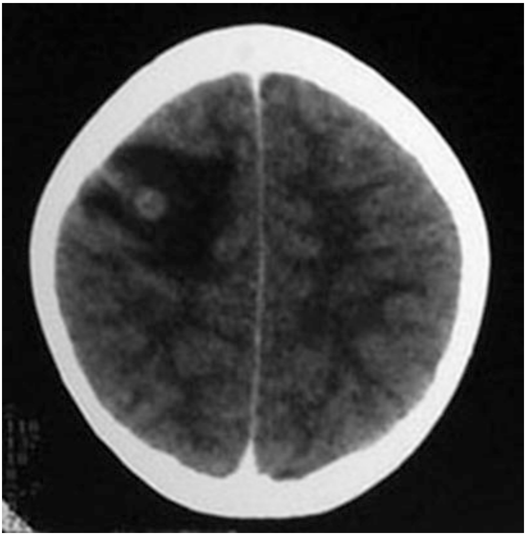


FIGURE 1.16 The right sided small lesion and edema are squeezing neighboring sulci and gyri similar to the schematic illustration in Fig. 1.15 above. Note the low density of the edema surrounding the lesion. (The inner core of the brain hemispheres consists of fibres and is called the white matter. The outer layer consists of the brain cells proper and is called the cortex or gray matter.) The white matter normally appears less dense than the cortex as seen on the left hemisphere in this scan. It is referred to as gray white differentiation on the CT scan. The edema from the lesion is darker than the normal white matter density but *it is not as dark as CSF*

where the CSF goes when it is squeezed, we will get there by and by. For now, let us try and name the CSF spaces and some parts of the brain. Sounds ominous like a top-level course in neuroanatomy! Don't despair; I know it is not many people's favorite subject, so we will keep it very simple. Let us start by naming some of the CSF spaces in Fig. 1.13 above. Let us look at the first row of four images, the left two of which are reproduced in Fig. 1.19.

The illustration in Fig. 1.20 shows that the brain is made up of gyri and sulci (gyrus and sulcus in singular form). The

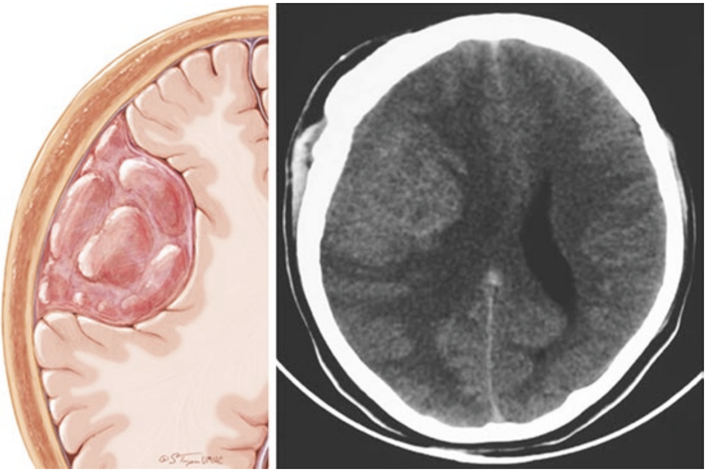


FIGURE 1.17 Drawing of the effects of an extra axial mass on the brain and a CT scan showing an ISODENSE MASS. Using the principles we learnt earlier, can you detect asymmetry in the two halves of the scan? Can you make out where the tumor is? (Note = it is isodense with brain). Start first by working out which side has the abnormality and then look for the abnormality. Yes, you read correctly. First decide which side is abnormal then look for the abnormality. ***(And this is the clue: whenever there is a pressure effect or mass effect, the CSF is the first thing to be displaced. If you think back in this chapter, we started with what distorts the sulci and progressed to what will distort the sulci and gyri. In a brain CT scan, a general rule of thumb is that the half with the least amount of CSF is likely to be abnormal. That goes without saying if the CSF is the most easily displaced component of the cranium and the lesion is likely to start displacing CSF from its immediate vicinity! Hence, the left with the large dark CSF space is the normal side and the right without any CSF space is abnormal. Now can you make out the abnormality? It is isodense; for instance, same density as brain so you will need your skills at pattern recognition to identify the abnormality. Use pencil and paper and sketch your impression of the tumor before you look at the next page which contains the contrast CT scan highlighting the tumor*** (Fig. 1.18)***. We will come back to contrast enhancement in the chapter on tumors)***

FIGURE 1.18 The tumor appears bright following contrast enhancement and you can gain the impression that the brain is squashed in all directions. I will like you to make one important observation on the opposite side to the tumor. You can see the uniform low density of the CSF in the ventricle and then the white matter and then the cortex with bright streaks in it before you reach the skull. You should make a mental note of the difference in density between the white matter next to the ventricle and the gray matter next to the skull. This is called gray white differentiation, a phrase that surfaces frequently usually when this distinction is lost in severe brain edema

sylvian fissure you see in the picture correspond to the sylvian fissure we identified on the CT scan in Fig. 1.19. This fissure separates the frontal and temporal lobes and it is the area through which the carotid arteries and the branches enter and supply the brain hence the place to look for blood when we are looking for evidence of subarachnoid hemorrhage (SAH). This point will be clear when we get to the chapter on SAH, but you can see the

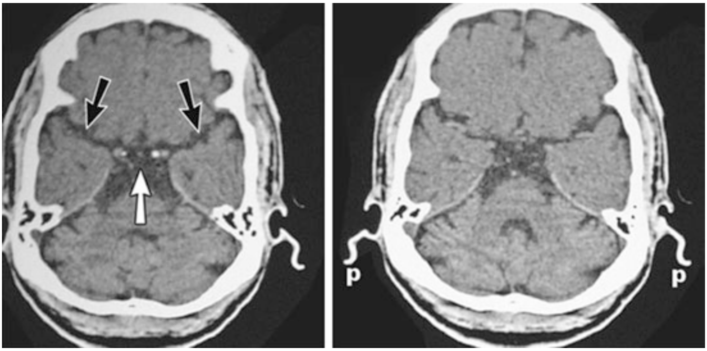


FIGURE 1.19 Right and left ***sylvian fissures*** (black arrows) meeting at the ***suprasellar cistern***. You can trace these narrow CSF pathways in each successive slice until it breaks up into small channels. It is present in every brain CT scan but not always visible due to variations in their size but you must look here for evidence of CSF distortion or subarachnoid hemorrhage! Outside the skull you can see the cartilage of the pinna (p), another important point of reference as you navigate the CT images

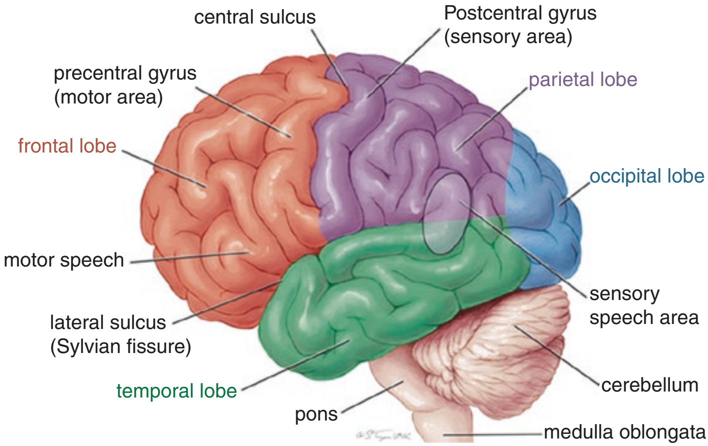


FIGURE 1.20 Pictorial illustration of the brain. Here is a reminder for those who have not recently graduated from a neuroanatomy course! Note the gyri are all separated by sulci—crevices and canyons—of the brain. (The Sylvian fissure (large and deep sulcus) is the Grand Canyon of the brain with important structures contained in it)

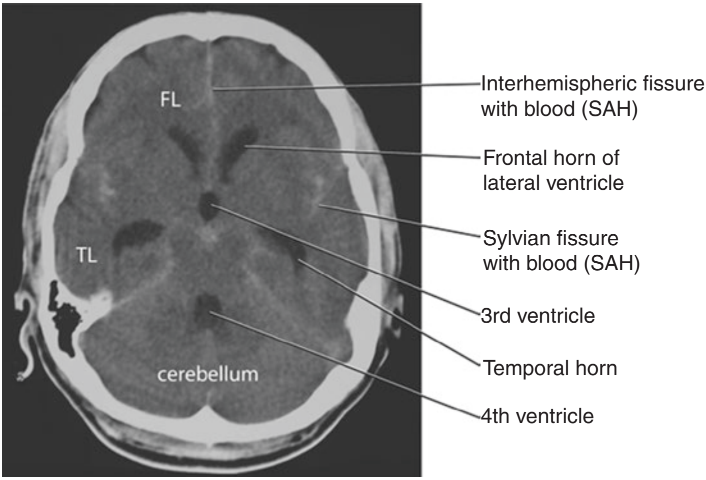


FIGURE 1.21 CT scan showing subarachnoid hemorrhage (SAH) and hydrocephalus. The mirror image nature of brain CT scans (symmetry) is apparent in this illustration. The temporal horns are normally collapsed and not easily seen, so their enlargement in this CT scan is abnormal and the third ventricle is rounded instead of being slit-like (See Chaps. 3 and 4 for SAH and hydrocephalus respectively)

obvious connection and the reason why this CSF space is important. *The sulci are roofed over by the arachnoid membrane* (Chap. 2) *to form the subarachnoid space which is continuous throughout the brain surface hence blood can flow through these spaces to any where intracranially!* In Figs. 1.21 and 1.22, the sylvian fissure, the interhemispheric fissure and the subarachnoid spaces over the surface of the brain are filled with blood leading to failure of circulation of CSF hence the hydrocephalus (enlarged ventricles—Chap. 4). Note that the pineal gland is just behind the top of the third ventricle as in Fig. 1.22.

These observations will conclude the introduction. Pleas revise the interactive portions of this chapter including the exercises.

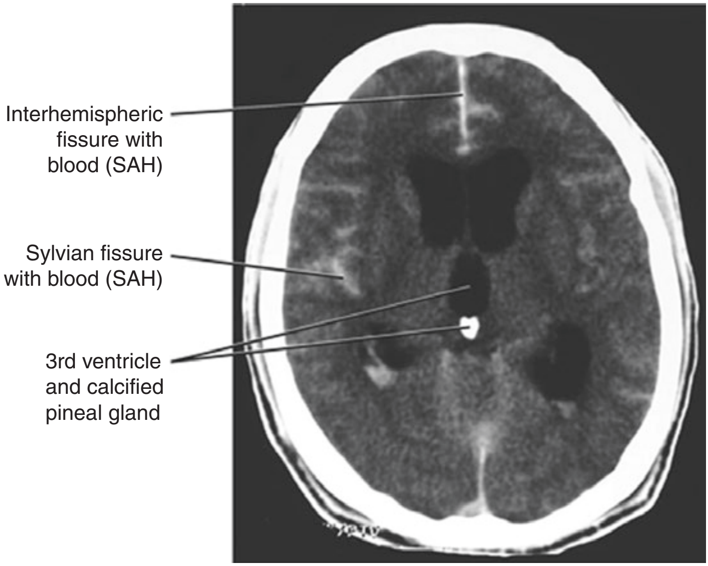
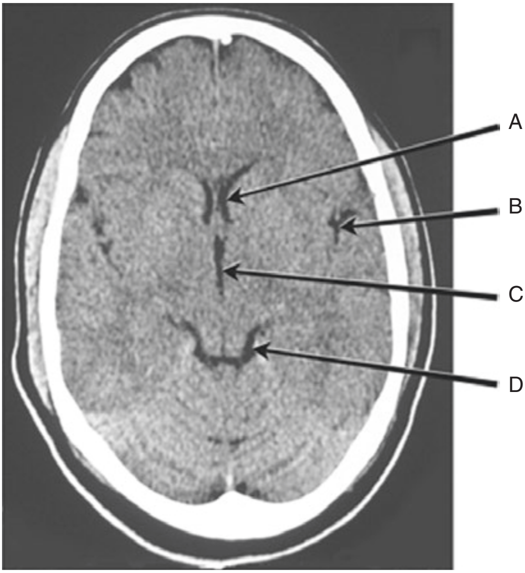


FIGURE 1.22 CT showing subarachnoid hemorrhage in the CSF spaces. Note the difference in density between the calcified pineal gland (normal) and the blood in the Sylvian fissure and the interhemispheric fissure. Also note that the pineal gland is directly behind the third ventricle

Exercise 2 Can you identify what the arrows are pointing to in this normal CT scan?



Chapter 2
Head Injury

2.1 Introduction: Intracranial Hematomas

From the last chapter we learnt that acute blood is hyperdense (whiter) compared to the brain. In this chapter we will use that information to identify the various lesions that can occur in the brain following trauma. Although diffuse injury is more common (Figs. 1.10, 1.12 and 1.14), the vast majority of emergency neurosurgical intervention in trauma involves the evacuation of mass lesions like epidural and subdural hematomas as well as intracerebral hematomas hence we will focus on identifying these lesions promptly. In Fig. 2.1, you should now be able to confidently identify the blood clots. The first thing to recognize is that the blood clot in each case is closely related to the skull. As a matter of fact, it is separating the brain from the skull. You will easily appreciate from further examination of the images that in Fig. 2.1a the clot is biconvex, shaped slightly like an egg (acute epidural hematoma, EDH), whereas in Fig. 2.1b the clot is crescent shaped like a ***new moon*** draped over the surface of the brain (acute subdural hematoma, ASDH).

In the majority of cases this simple difference in shape accurately distinguishes an epidural hematoma from a subdural hematoma. We will come back to this in more detail below. Your understanding of the conceptual (anatomic)

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In Clinical Practice, https://doi.org/10.1007/978-3-030-14828-7_2

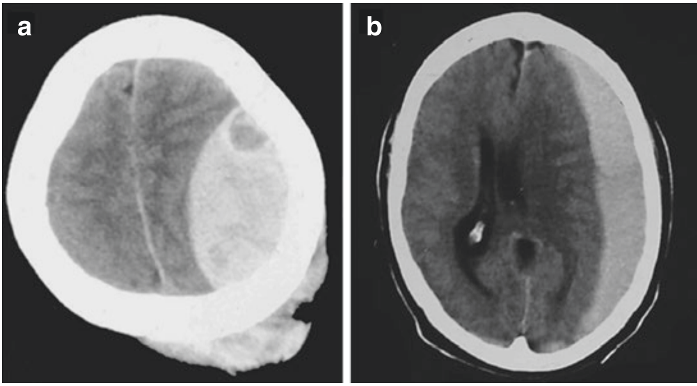


FIGURE 2.1 Non-contrast CT scan showing an acute epidural hematoma (with overlying scalp swelling) (**a**) and acute subdural hematoma (**b**)

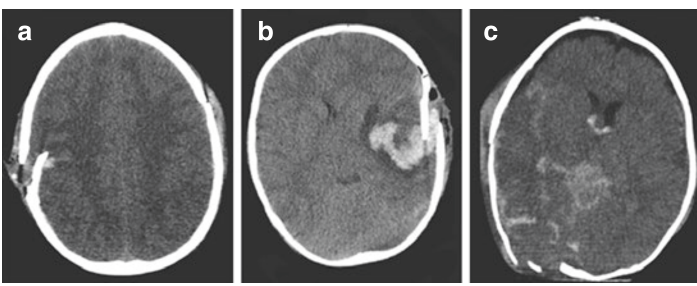


FIGURE 2.2 CT scan showing (**a**) depressed skull fracture; (**b**) depressed fracture and associated traumatic intracerebral hematoma and; (**c**) depressed fracture and associated traumatic SAH and contusions

basis for the difference in the CT appearance of these two lesions is not only important for your accurate use of the terms but epidural hematoma patients behave significantly differently from patients with acute subdural hematoma hence the distinction is important.

Depressed skull fractures are easy to identify clinically (on the patient) and on the CT scan (Fig. 2.2), often signifying direct blow to the affected part of the skull. They could be associated with different kinds of brain hemorrhage as shown

here. Linear fractures are less easy to see on the CT scan and the "bone window" (see Fig. 2.21a, b) is essential for their diagnosis.

2.2 Acute, Subacute and Chronic Subdural Hematomas

The word 'acute' simply means recent; for instance, that the blood is still white or hyperdense on the CT scan; as opposed to 'chronic' when the blood changes color (density) to hypodense at about 3 weeks from the trauma. Subacute is the intermediate phase between acute and chronic—roughly when the blood is 1 week old and may appear isodense as in Fig. 2.3b.

2.3 The Brain Coverings (Meninges) and the Subarachnoid Space

The word '*sub*-dural' simply means *below* or *under* the dura and *extra*-dural or *epi*-dural simply means *outside or above* the dura. Figure 2.4 illustrates the layers of the brain and Fig. 2.5 graphically illustrates the naming (classification) of

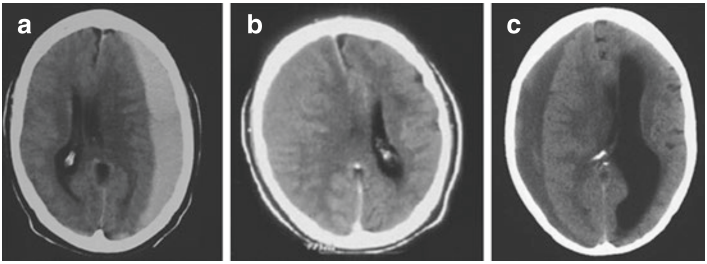


FIGURE 2.3 Showing (**a**) acute (hyperdense), (**b**) subacute (isodense) and (**c**) chronic (hypodense) subdural hematomas which represent three different stages of evolution (not the same patient). Note that the side with the blood clot has less CSF in all these examples

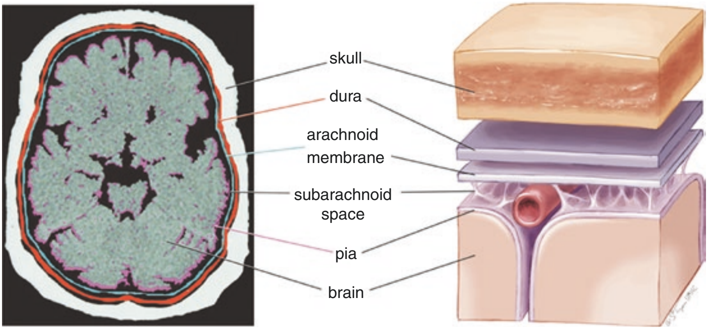


FIGURE 2.4 Schematic illustration showing the different layers covering the brain

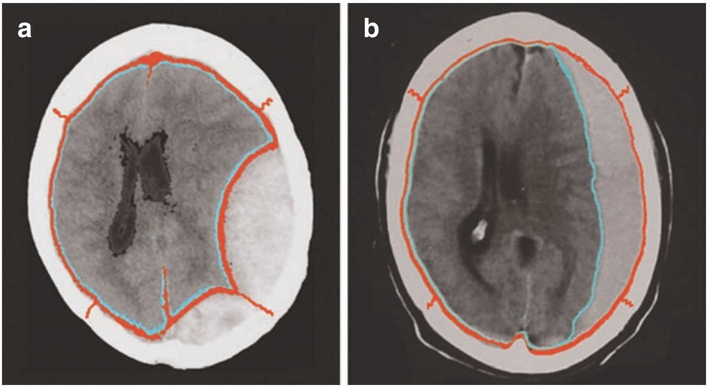


FIGURE 2.5 Schematic illustration showing the difference between acute epidural hematoma (**a**) and acute subdural hematoma (**b**). Can you confidently distinguish the AEDH from the ASDH? Notice that the thick dura mater inserts into the skull and confines the blood clot to this insertion boundaries hence the biconvex shape of the epidural hematoma

blood clots as epidural or subdural. In simple terms the classification is based on whether the clot is above or below the dura.

Note particularly that the dura is a tough relatively thick membrane and it is illustrated as the red layer under the

skull. If the blood collects between the skull and the dura, then it is called an epidural hematoma as it is outside the dura. The next layer is the arachnoid membrane illustrated by the light blue color which in life is transparent and flimsy (very much like cling film) and it lines the inner surface of the dura, thus a *potential* space exists between the arachnoid and the dura. This is called the subdural space which is normally collapsed in life but when bleeding occurs into this space it is called a subdural hematoma (see Figs. 2.3 and 2.5).

Further examination of Fig. 2.4 shows that the third layer to cover the brain is the pia mater which in fact tightly hugs the brain going into every valley (sulcus) and mound (gyrus) that makes up the surface of the brain. It is illustrated by the pink layer in Fig. 2.4. Since the arachnoid does not hug the brain tightly but bridges over the sulci, a relatively large space is formed between the arachnoid and the pia. This space is ***filled with CSF*** and since it is below the arachnoid, it is called the subarachnoid space (Fig. 2.4). The bigger blood vessels of the brain lie in this space and bleeding into this space is called subarachnoid hemorrhage (Figs. 1.8, 1.9, 1.21 and 1.22) (see also Chap. 3).

The last layer covering the brain is the pia mater. *Blood clots or tumors in the brain deep to the pia mater are called* ***intra axial*** *and those outside the pia mater are called* ***extra axial.*** This distinction is important when we talk about tumors and even hematomas. The image in Fig. 2.6 illustrates a traumatic intracerebral hematoma, for instance inside the brain (within the pia mater). Notice that the ventricle on that side is squashed and that is called ***mass effect***: for instance, pressure from the clot squeezing the surrounding brain and displacing the CSF.

2.4 The Parts of the Skull and Naming of Hematomas

The skull is the ultimate covering of the brain and because epidural hematomas in particular are often named after the skull bone they are lying under, it is important to remind

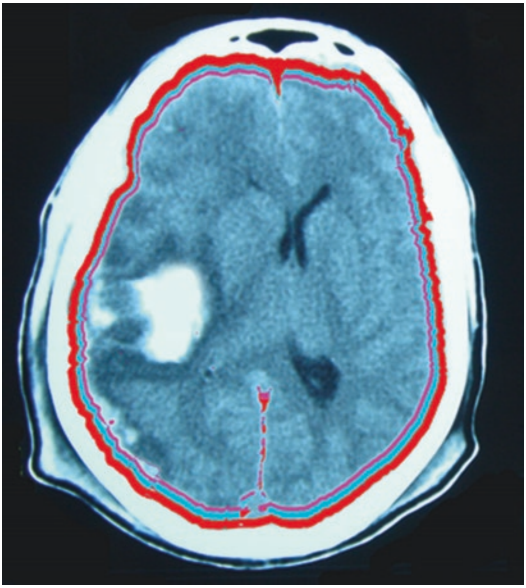


FIGURE 2.6 CT scan showing traumatic intracerebral hematoma—within the parenchyma of the brain—for instance inside the pia mater

ourselves of the parts of the skull. The bones of the skull are illustrated in Fig. 2.7 and they are joined at their margins by saw-teeth joints called sutures, where the dura inserts very firmly into the skull (Figs. 2.5 and 2.7).

This diversion into anatomy is important because, the lobes of the brain roughly correspond to the portion of the skull they relate to as well. For instance, the frontal lobe of the brain is under the frontal bone of the skull and so are the parietal, temporal and occipital lobes with slight overlaps (compare Figs. 1.20 and 2.7). The dural insertions into the skull (at the sutures) leave very deep impressions on the skull which are readily evident as seen in this picture of the interior of the skull (Fig. 2.8). The coronal suture (CS) separates the frontal bone from the parietal bone and the lambdoid suture separates the parietal bone from the occipital bone.

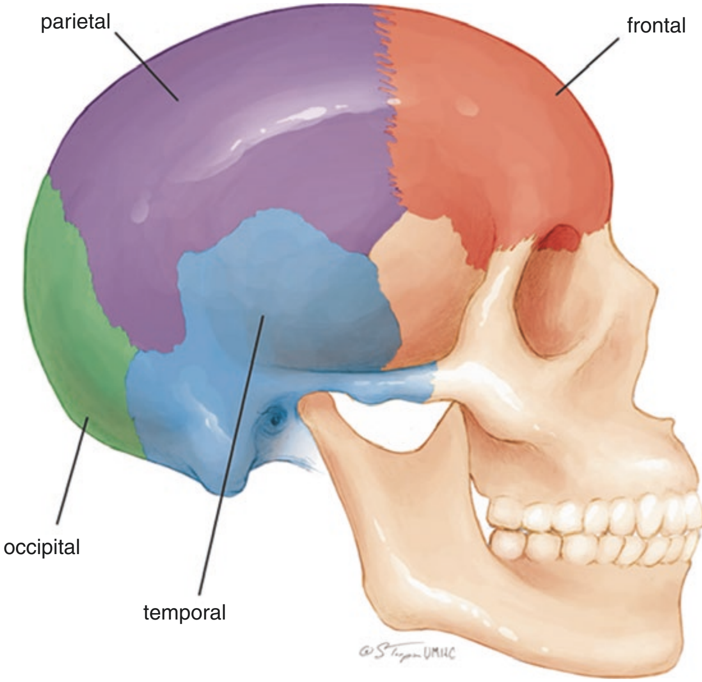


FIGURE 2.7 Parts of the human skull

Epidural hematomas do not normally cross these suture lines as the dura insertion is tough thereby restricting the enlarging clot to the confines of the sutures of that particular bone hence, they enlarge like a balloon and compress the brain and appear biconvex.

It is important therefore to appreciate that epidural hematomas are biconvex in appearance because the dura is fixed (inserted firmly into the skull Fig. 2.9) at the sutures, whereas the subdural space is continuous over the surface of the brain hence acute subdural hematomas (Fig. 2.10) and chronic subdural hematomas (Fig. 2.11) spread over the surface of the brain and assume a crescent shape.

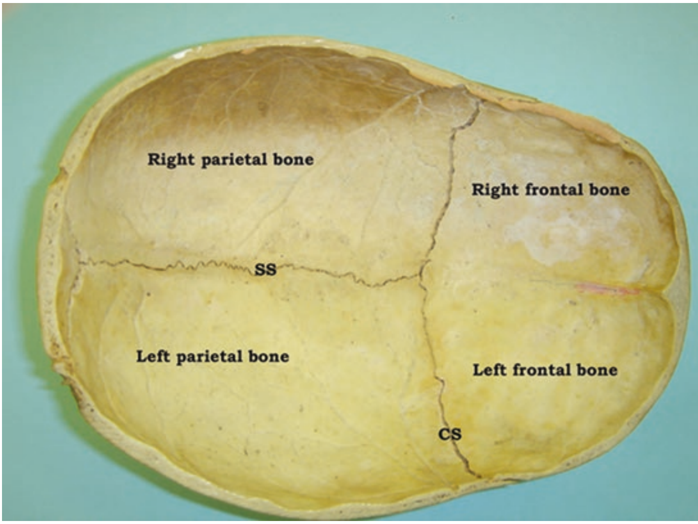


FIGURE 2.8 Interior view of the skull showing some of the dural insertions (sutures). (*CS* coronal suture, *SS* sagittal suture)

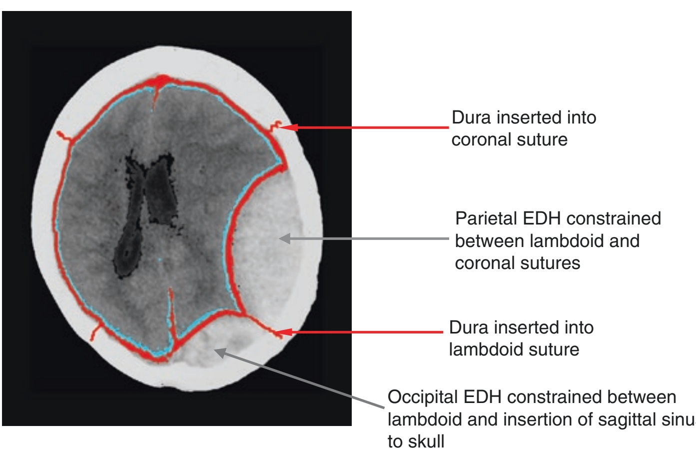


FIGURE 2.9 CT scan with line drawings showing the dural insertions and epidural hematomas restricted by the sutures

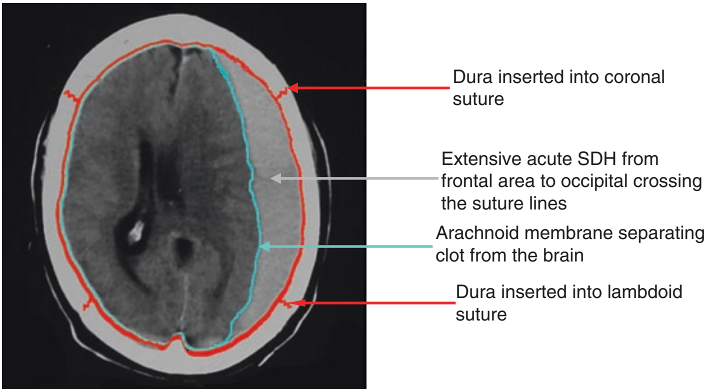


FIGURE 2.10 CT scan with line drawings showing acute subdural hematoma which is spread over the whole surface of the brain since the subdural space is continuous. Compare with EDH (Figure 2.9) which is restricted by suture lines hence biconvex in shape

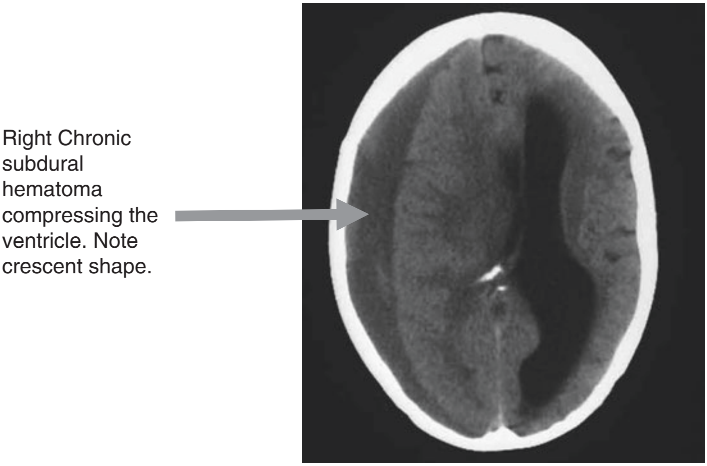


FIGURE 2.11 CT scan showing right *chronic* SDH; demonstrating again that subdural hematomas can spread from frontal area to occipital area without restriction so they tend to be shaped like a sickle or crescent with the concave surface towards the brain

2.5 The Base of the Skull

The skull base serves as the cup that contains the brain. In doing so, it serves as the gateway for blood vessels to reach the brain and for the spinal cord to leave the skull. This "cup" is divided into three different sections (Fig. 2.12) called anterior cranial fossa (pink); middle cranial fossa (orange) and posterior cranial fossa (yellow). (A fossa simply means a

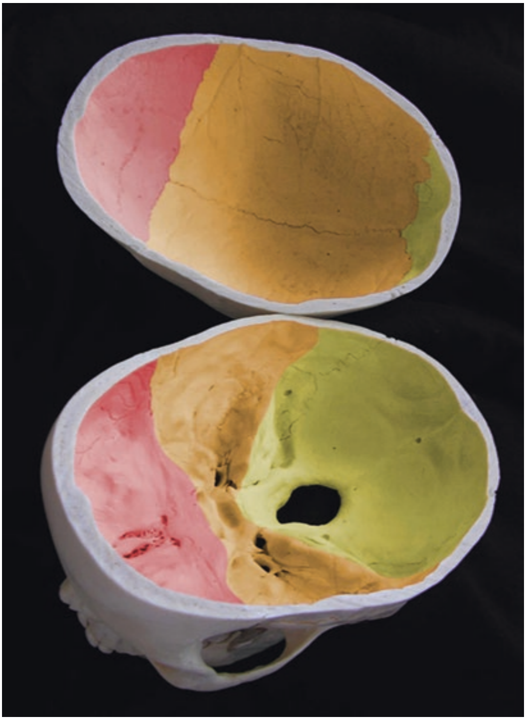


FIGURE 2.12 Interior of skull base showing anterior cranial fossa (pink); middle cranial fossa (orange) and posterior cranial fossa (yellow). The roof of the skull is sometime loosely referred to as the convexity because of the shape, hence fractures here are called convexity fractures as opposed to skull base fractures which affect the cup (base of the skull)

'ditch': Latin). The big hole in the posterior fossa transmits the spinal cord and is called the foramen magnum. The rest of the posterior cranial fossa is filled by the cerebellum, the pons and medulla. The temporal lobe sits in the middle cranial fossa and the frontal lobe rests in the anterior cranial fossa.

2.6 The 5S's of Any Hematoma!

What else would you consider important to note about a blood clot if you found one on a brain CT scan? STOP and write down your answer to that question before you proceed to look at the simple suggestions I have outlined as the 5S's for easy reference.

2.7 The First S Stands for *S*ize

In ***every*** CT scan there is a scale in centimeters by each image that enables you to measure accurately the thickness of the clot and the length measured from front to back of the clot. In addition, you can count the number of slices in which the clot is visible. Thus, by saying that a clot is about 4 cm thick and visible on six slices (each slice is about 0.5 cm thick or as specified) and measuring 5 cm from front to back, you have described a clot of approximately 60 cm^3 volume ($4 \times 5 \times 3$). This may not be very informative so as you get more experienced you will be considering mostly whether a clot is immediately life threatening or not and your responsibility is to transmit that information to a neurosurgeon. The things that enable you make that judgment in addition to the size are the other four S's so read on!

Another practical way of conveying size is to say how many times the clot is thicker than the skull! This allows the listener to estimate how big the clot is relative to an average skull thickness. The size together with the other 4 S's will give you an indication of the urgency of any clot so let us go ahead and explore them. Note however that what the neurosurgeon

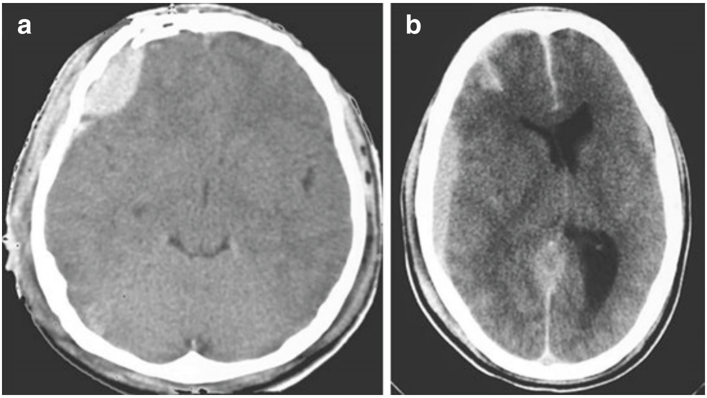


FIGURE 2.13 Example of small acute epidural hematoma (**a**) and a small acute subdural hematoma (**b**)

decides to do with each of these hematomas will depend on the clinical condition of the patient hence the ***Symptoms and signs (the neurological symptoms and signs of the patient)*** are very important. The epidural hematoma (Fig. 2.13a) was associated with a compound depressed fracture, consequently it was operated on and the patient with the subdural hematoma (Fig. 2.13b) was 18 years old and deeply comatose with ipsilateral dilated pupil so a decompressive craniectomy with evacuation of the subdural hematoma was carried out. 'Although the information you get from the CT scan is the same, the neurosurgical intervention is ALWAYS determined as much by the clinical features hence ***always seek the background clinical information when looking at a brain CT scan'***

2.8 The Second S Therefore Stands for *S*ymptoms and Signs

By and large this is the most important part of looking at a brain CT scan because you always have to make a judgment whether the abnormality you see is consistent with the clinical findings. On the other hand, the clinical history guides you on where to look in detail on the CT scan. For instance;

if the main symptom is left hemiparesis then you immediately focus on the right side of the brain. Similarly, if a right-handed patient presents with speech disturbance following trauma you will look in detail at the left temporal lobe for abnormality.

However, for large hematomas, even if the patient is clinically well, the blood clot is evacuated because catastrophic neurological decline can occur, hence they should be treated as extremely urgent (see below). Perhaps the most important clinical advice to the frontline doctor with regards to emergency brain CT scan for trauma or any other reason is for you to LOOK AT THE SCAN AS SOON AS IT IS DONE. ***This book is written to provide you a simple and easy guide on how to look at a brain CT scan and make a valid judgment for your next management action.*** It does not replace a formal report from a radiologist but allows you to evaluate the CT scan and make a decision in the vast majority of cases thereby allowing you to be more efficient and improve your prioritization when multiple injuries occur. The indications for a brain CT scan in trauma are: a ***history*** of altered level of consciousness, focal neurological deficit, skull fracture, persistent severe headache with or without vomiting and seizures following trauma to the head. The exercises at the end of this chapter will illustrate further the importance of clinical correlation in reviewing a brain CT scan but suffice it to say that large clots like the ones illustrated here (Fig. 2.14) invariably are evacuated as there is significant ***shift of the brain***.

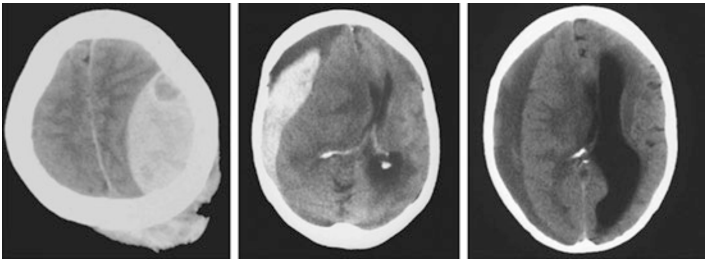


FIGURE 2.14 Large hematomas with mass effect. **Emergency action required!**

2.9 The Third S Stands for *S*hifts and Serious Consequences

The word shift implies that there is normally a boundary and indeed there are several boundaries. The midline of the brain is marked by the falx cerebri, a sheet of dura hanging down from the top of the skull (sagittal suture). As the blood clot in say Fig. 2.14 enlarges, it squashes the brain and the CSF is the first thing to be squeezed out (literally). It is very much like a sponge soaked with water. When you squeeze, the water goes out first. Similarly squeezing of the brain by a clot leads to loss of CSF from the intracranial to the lumbar (spinal) cistern. This is followed by the clot pushing the brain across the midline as well as squashing it together like in Figs. 2.14 and 2.15.

The importance of these shifts is that the ***pressure*** on the brain (increased intracranial pressure) also prevents adequate amount of blood reaching the brain from the heart. And if the temporal lobe is pushed over the edge of the tentorium it compresses the third nerve giving rise to a fixed and dilated pupil on the same ***side*** as the clot (tentorial herniation, Fig. 2.16).

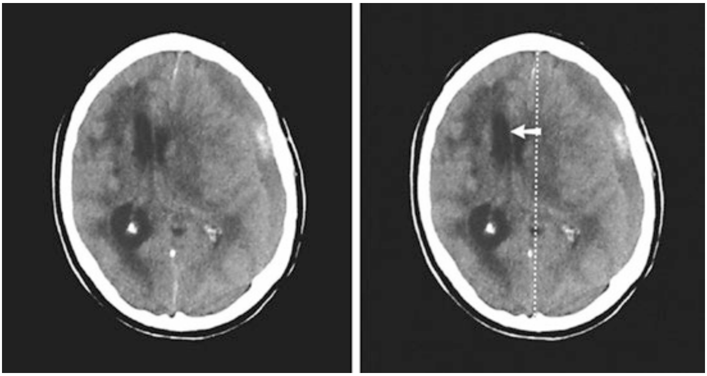


FIGURE 2.15 Chronic subdural hematoma compressing the brain and shifting the midline of the brain from the white line to the arrow tip

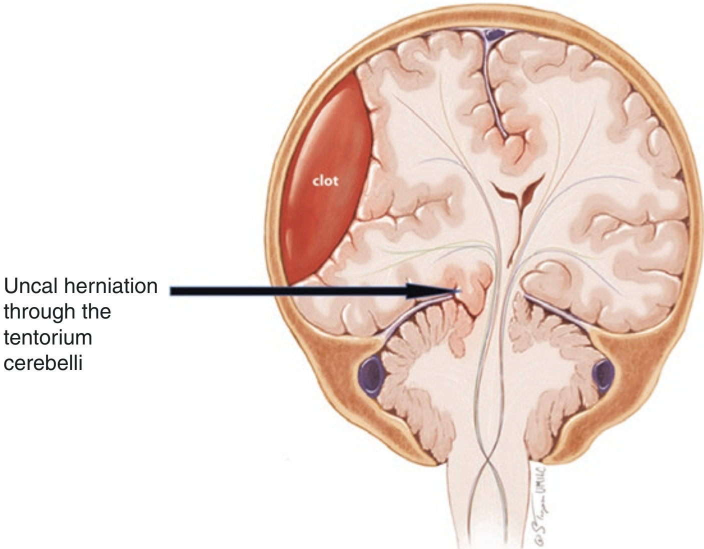


FIGURE 2.16 Schematic diagram showing tentorial herniation. (Note that this finding is an extreme emergency requiring immediate neurosurgical intervention. ***In this situation, a double strength of adrenaline is required—NOT for the patient but for the frontline doctor to move fast!)***

2.10 The Fourth S Stands for *S*ide

The CT scan image normally carries with it important information such as the **patient's name**, **age or date of birth** and **the date of the scan**. But equally important it also states which side is '**left**' and '**right**'. By convention the CT image is viewed as if you are facing the patient: so that the right side of the brain appear on the viewer's left and the left brain appear on the viewer's right on the screen. However, as Fig. 2.17 shows, the image can be horizontally flipped electronically or manually misplaced in the X-ray viewing box and unless you ***check the labeling 'religiously' every single time***, you risk misleading yourself about the side and transmitting that erroneous message with dare consequences.

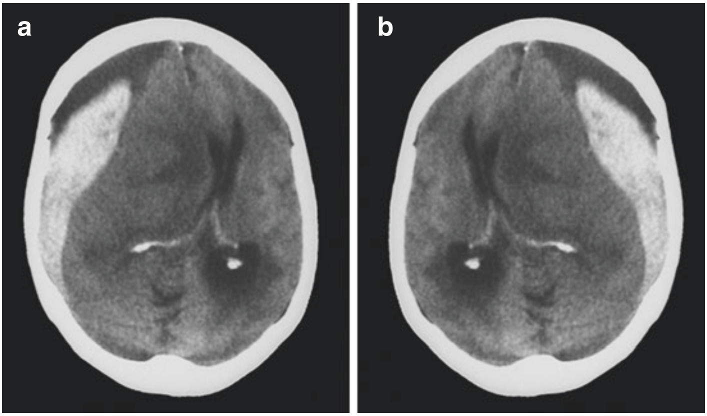


FIGURE 2.17 (**a**, **b**) Which side of the brain is this clot? It is so easy to inadvertently flip the CT films, or the convention adopted maybe different from what you are used to; so ***ALWAYS CHECK THE LABELLING OF LEFT AND RIGHT!*** See Figure 2.18

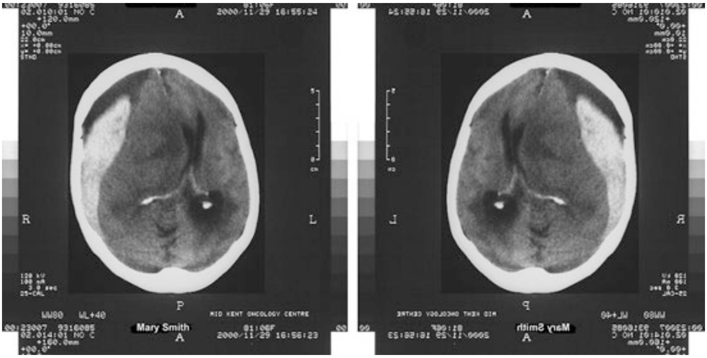


FIGURE 2.18 Showing the ease with which error can occur if the side labels are not checked ALWAYS!

Everyone has heard of surgeon's operating on the wrong side. Misreading the side on the CT scan is one common reason for this error! Beware!

Note that Fig. 2.18 is exactly the same as Fig. 2.17 except that I removed the labels from Fig. 2.17. It is obvious that without looking at the labels, the mistake in Fig. 2.17 cannot be

corrected. Finally, CT films are only images and clearly can be corrupted or be subject to any number of errors. *As a result, an opinion on the CT scan is meaningless unless correlated with the patient's clinical history and signs*. No where is that assertion any truer than with regard to the side of the lesion.

2.11 The Fifth S Stands for the *S*ite of the Hematoma

The site of a clot is very important because hematomas inside the brain are classified (and named by their ***location***). Just like your name is your identity, where a clot is located defines the identity of that clot. We saw earlier that epidural and subdural hematomas are so named because of their location above the dura or below the dura respectively. The second dimension in considering ***site*** is the part of the brain or the skull the clot is related to. For instance, Fig. 2.19a is called a small left frontal epidural hematoma because it is an epidural hematoma located between the frontal bone and the left frontal lobe of the brain. Similarly Fig. 2.19b will be called a large right frontal and temporal subdural hematoma because it is a subdural clot located both in the frontal and temporal areas. You will notice two things. First is that the subdural hematoma spread across two areas of the cranium freely because there are no barriers (sutures) restricting it like you find with the epidural hematoma which is convex and confined to under the frontal bone alone due to the restricting effect of the dura inserting into the coronal sutures (Figs. 2.8 and 2.9). The second thing is that in naming these hematomas, I have been careful to mention the sides just like we learnt above. Can you identify any other things about Fig. 2.19b that are important? See below.

The following phrases about ***site*** may be clarified at this time: ***intracranial hemorrhage or hematoma*** (cranium = skull) refers to hemorrhage anywhere within the skull, of any cause. Therefore, epidural hematoma, subdural hematoma and subarachnoid hemorrhage and ***intracerebral hematoma*** are all different types of intracranial hemorrhage

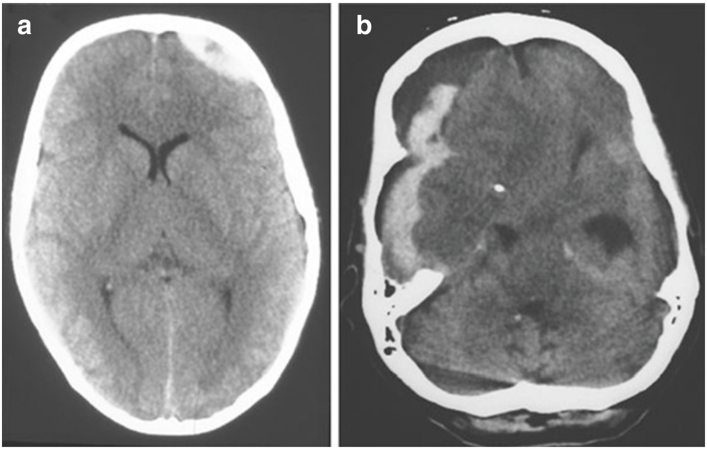


FIGURE 2.19 (**a**, **b**) Showing a small left frontal acute epidural hematoma (**a**) and a large right frontal and temporal acute subdural hematoma (**b**). Can you comment on the acute subdural hematoma with regards to size, shift, and severe consequences?

distinguished only by the layer (depth in the brain) in which the blood clot forms. Note that *intracerebral hematomas* are clots located entirely within the substance of the brain or the larger part of it is in the substance of the brain but may track into the ventricles or into the subdural space. Contusions are small intracerebral hemorrhages that often occur in areas where brain comes in contact with the very rough floor of the skull like the frontal lobe (Fig. 2.21a) and the temporal lobe. They also occur in deeper brain structures from shear injury (Fig. 2.20) and larger contusions form intracerebral hematomas (Figs. 2.2 and 2.6).

Clots are defined by:

- Size
- Symptoms and signs
- Shifts
- Side
- Site

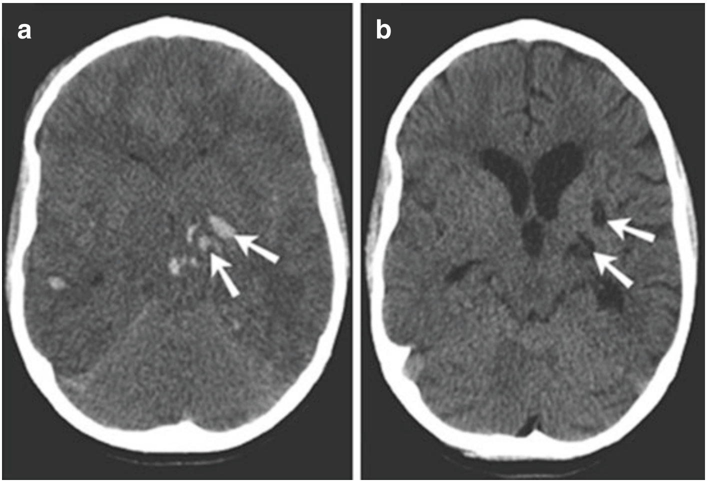


FIGURE 2.20 CT scan showing early and late appearance of left basal ganglia and external capsule contusions. Note the right temporal contusion also in the early scan. In the late scan the contusion has resolved leaving behind low-density cavity

The red flags in Fig. 2.19b that I expected you to identify were the subfalcine herniation, the significant midline shift to the left and contralateral hydrocephalus indicated by the enlarged temporal horn. All these features come to one conclusion: **Emergency action required!** In other words, even if the patient appears stable and has a clot like the one in Fig. 2.19b with compression of the brain and midline shift, they are likely to deteriorate quickly, hence emergency neurosurgical intervention is required. And if they are comatose with a scan like that then it constitutes an ***extreme emergency!***

Although hematomas have been emphasized here, by far the more common abnormality seen on brain CT scan following severe trauma is swelling from diffuse injury such that less than 25% of coma producing head trauma has a blood clot requiring evacuation. Figure 2.21 shows two children: one with a skull fracture and brain contusions but not diffuse swelling (images a–c) and the other with diffuse axonal injury (images d–F). The skull fracture child made a complete recovery, but

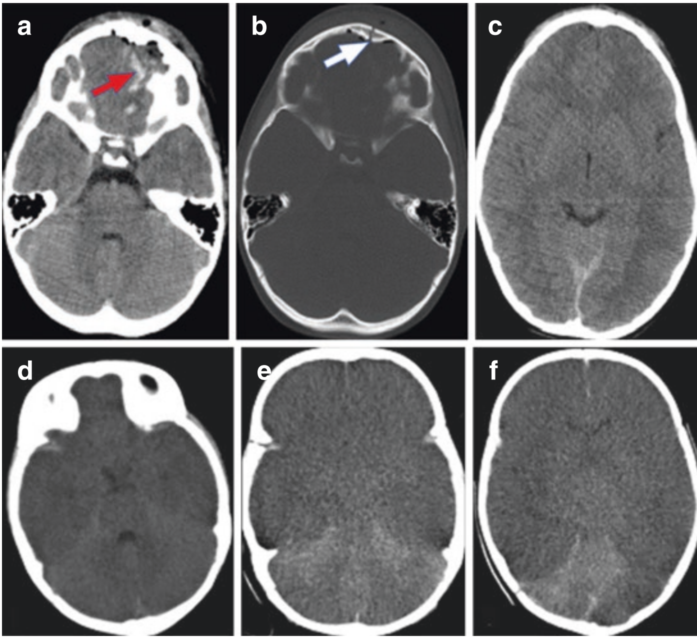


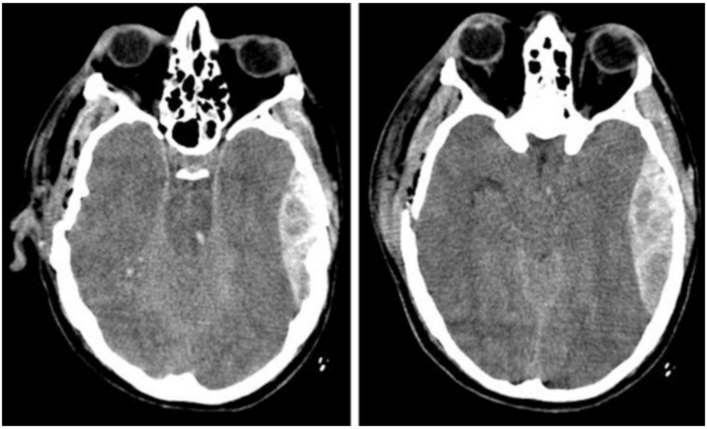
FIGURE 2.21 Examples of different traumatic lesions: (**a**), (**b**) and (**c**) are CT scans from a 6-year-old with left frontal fracture and contusions from a motor vehicle collision. Images (**d**), (**e**) and (**f**) are from a *different* child with abusive head trauma (AHT) (shaken baby syndrome or non-accidental trauma) with diffuse axonal injury. (**a**) Shows left frontal contusion (red arrow); (**b**) same scan as (**a**) but in bone window showing left frontal skull fracture (white arrow) which is difficult to see on the normal window in (**a**); (**c**) illustrates the ready visualization of the third ventricle signifying the absence of diffuse swelling; (**d**, **e**) are from a different child with abusive head trauma with the scans done three days apart showing the absence of the fourth ventricle in (**e**) due to swelling and the loss of grey white differentiation in (**e**, **f**)

the diffuse axonal injury was fatal. Thus, in Fig. 2.21a–c despite the significant skull fracture, brain swelling is minimal, and the third ventricle is clearly visible. The clear visualization of the third ventricle and the basal cisterns is usually presumptive

evidence that there *may not be* severe diffuse brain swelling. On the other hand, complete lack of visualization of the third ventricle and basal cisterns is indicative of severe swelling as in Fig. 2.21f. Also, if you compare Fig. 2.21d, e which are scans done 3 days apart on the same child, it is obvious that the fourth ventricle is no longer visible in Fig. 2.21e due to swelling. There is also loss of gray white differentiation in the image series (Fig. 2.21d–f). (*Note that* Fig. 2.21a, b *are the same slice of CT scan but in* Fig. 2.21b *the window level has been set to show bony anomalies clearly. This is called the bone window and it is essential for seeing linear fractures especially at the base of the skull.)*

To summarize, clots over the motor cortex (posterior frontal) will cause hemiparesis on the contralateral (opposite) side. And commonly left temporal contusions and hematomas will present with dysphasia because in the majority of right-handed people the left temporal lobe is responsible for speech. Thus, you can see that the site of a clot is very important. I encourage you to briefly look over Fig. 1.20 again so that you are familiar with the parts of the brain and their function.

Exercise 3 Can you name any three abnormalities on these scans?



Exercise 4

1. What does the loss of grey and white differentiation mean in Fig. 2.21f
2. Why are epidural hematomas biconvex in shape?
3. What suture separates the left and right parietal bones? (Fig. 2.8)

Chapter 3
Brain Haemorrhage and Infarction: Stroke

3.1 Subarachnoid Hemorrhage

Bleeding into the subarachnoid space is called subarachnoid hemorrhage to distinguish it from bleeding into the substance of the brain proper which is called intracerebral hemorrhage or intracerebral hematoma. The distinction is important because spontaneous subarachnoid hemorrhage is most frequently caused by aneurysm rupture which is ***fatal*** in one third of cases often before they get to the hospital. And second hemorrhages carry a higher fatality rate hence it is imperative to detect any subarachnoid hemorrhage and treat the underlying aneurysm (Fig. 3.1). Aneurysms are blowouts of the major arteries as they enter the base of the brain close to the skull base, especially at arterial bifurcations.

The basic concept to start from is that the subarachnoid spaces in the brain are practically continuous spreading from left to right across the midline and from the base of the skull to the top (Fig. 3.2). The second concept to appreciate is that the main blood vessels in the brain ***travel*** in the subarachnoid space (Fig. 3.2) hence when an aneurysm ruptures, it bleeds into the subarachnoid space where there is very little to tamponade the bleed and stop it early! It also explains why bleeding easily spread from left to right and vice versa.

U. Igbaseimokumo, *Brain CT Scans in Clinical Practice*,
In Clinical Practice, https://doi.org/10.1007/978-3-030-14828-7_3

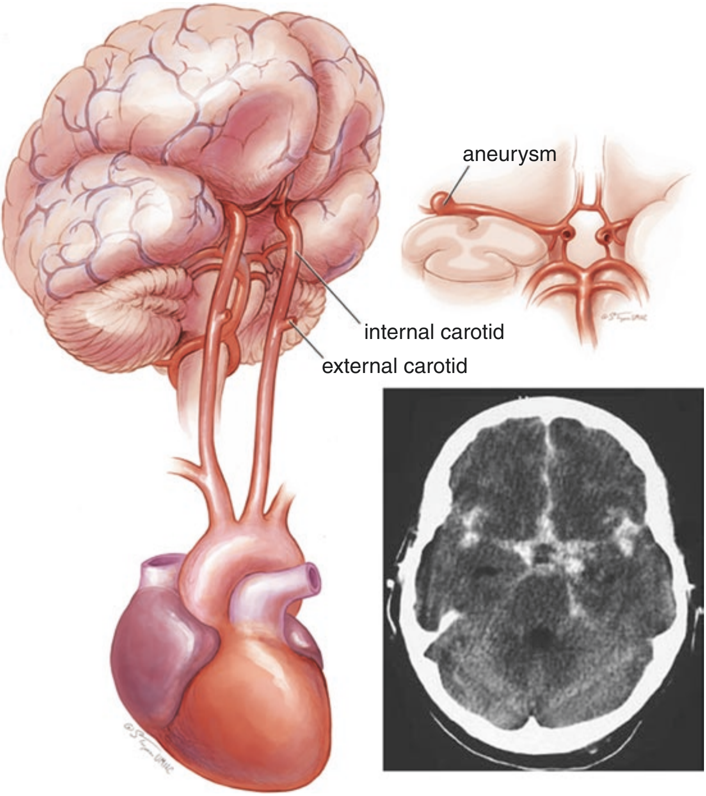


FIGURE 3.1 Drawing, showing the blood supply to the brain and illustrating an aneurysm in the middle cerebral artery. A CT scan showing widespread SAH from such an aneurysm is also shown. Compare with Fig. 3.2, an MRI showing how the vessels travel in the subarachnoid space and note that the subarachnoid space is continuous from right to left

The majority of aneurysms occur around the circle of Willis hence aneurysmal subarachnoid hemorrhage tends to appear mainly in the basal cisterns and sylvian fissure on CT scan and thankfully most cases are obvious as in Fig. 3.3.

If all SAH were as obvious as the images in Fig. 3.3 then this chapter would be very short! Not infrequently the

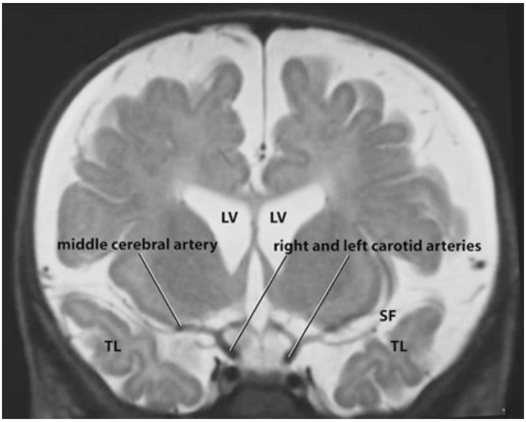


FIGURE 3.2 Coronal MRI at the level of the sylvian fissure (SF) showing the free communication of the subarachnoid space from the base of the skull to the convexity on either side and how the main blood vessels travel in the subarachnoid space. The carotid arteries divide into anterior cerebral and middle cerebral arteries. The left and right anterior cerebral arteries are linked by the anterior communicating artery and two posterior cerebral arteries are linked to each carotid via the left and right posterior communicating arteries, thus making up the circle of Willis—the arterial ring that supplies blood to the brain. (*LV* lateral ventricle, *SF* Sylvian fissure, *TL* Temporal lobes)

amount of blood maybe so small that the inexperienced physician could miss subtle features of SAH on the CT scan hence a systematic approach is required to examine a CT scan for clues.

It is important however to emphasize that the mere absence of visible blood on CT scan ***does not rule-out SAH.*** In centers with appropriate expertise a CT angiogram is performed to exclude an aneurysm. In centers where a CTA cannot be done reliably, it was not uncommon to perform a lumbar puncture in patients with a history strongly suggestive of SAH who appear not to have visible blood on the CT scan. In any event discussion with a neurosurgeon is highly recommended.

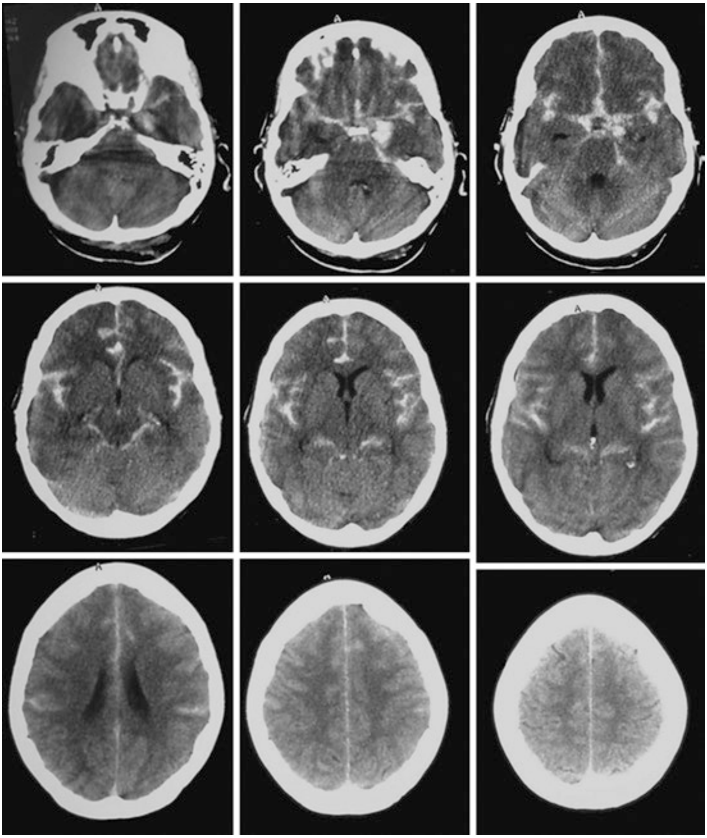


FIGURE 3.3 Non-contrast CT scan showing widespread SAH. Note the symmetrical outline of the left and right sylvian fissures and how the blood has outlined all the basal CSF spaces

Figure 3.4 shows different degrees of obviousness of SAH but the most important lesson is to note the usual locations when blood is obvious so that when SAH is not obvious, the usual locations can be ***scrutinized*** with a magnifying glass for any suspicious densities or other clue of SAH! With this background we can now consider the thought process involved in evaluating a ***patient***'s CT scan for SAH in the emergency room or anywhere for that matter. The following points are key to preventing error.

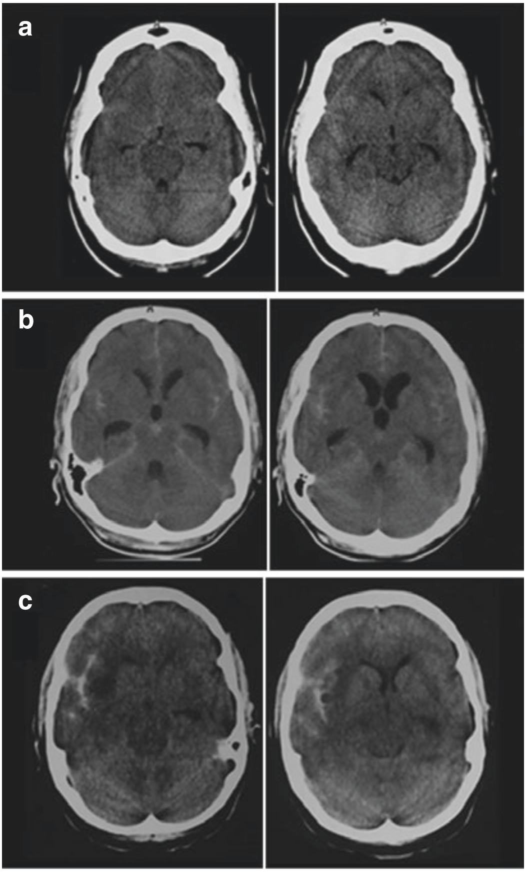


FIGURE 3.4 Shows different degrees of obviousness of SAH: (**a**) the hyperdensity in the interhemispheric and right sylvian fissure and ambient cisterns along with early hydrocephalus makes the diagnosis of SAH pretty secure. (**b**) The bilateral sylvian and interhemispheric blood (hyperdensities) is fairly obvious and the hydrocephalus is now clear cut with a rounded third ventricle and dilated temporal horns. (**c**) Here consideration of the right and left sylvian fissures show obvious blood in the right sylvian fissure. The important point however is that the left sylvian fissure is almost not visualized but it is obviously present! Therefore, in a suspected case of SAH the sylvian fissure should be inspected in detail with a magnifying glass knowing that if blood were present it would perhaps take the shapes shown in (**b**, **c**). (**d**) Shows a hematoma in the interhemispheric fissure along with intraventricular blood and bilateral sylvian fissure blood. SAH is obvious here

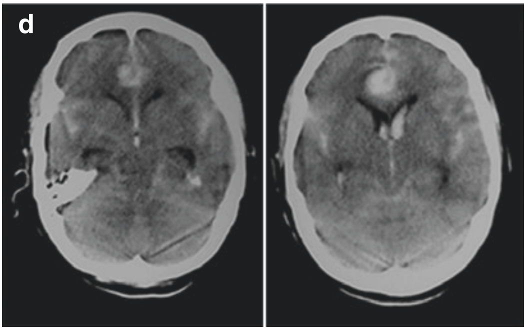


FIGURE 3.4 (continued)

3.2 First Clue in SAH Is the Clinical History

The first universally agreed principle is that when it comes to SAH the history is the key factor in determining the doctor's course of action or investigation of the patient. No where else is a good history as vital in the evaluation of a neurological patient as in SAH. Let us briefly examine the history as it applies to the brain CT scan interpretation. The sensitivity of a CT scan in picking up SAH is 95% within the first 24 h and this drops to 84% after 3 days and 50% at the end of a week. ***It is therefore obvious that the CT appearances of SAH change with time, hence a clear history of the time of onset of symptoms is important in your interpretation of the CT findings.*** The typical history is of sudden onset severe headache with or without loss of consciousness, often described as the worst ever headache the patient has experienced. As mentioned earlier if the CT scan is negative then a CT angiogram or a lumbar puncture is required to exclude SAH depending on the practice setting. And in cases with a highly suggestive history a neurosurgeon should be consulted to discuss the final disposal of the patient as angiography may still be required in highly selected cases even if the CT and lumbar puncture are inconclusive of SAH!

"Listen to the history with intent"
and
"Look at the CT scan with intent"
to find blood.

The following pages
will assist you
to learn where to focus
and
what to look for
on the CT scan
if SAH is suspected!

3.3 Where to Look for SAH: Usual Locations

The obvious cases of SAH like Fig. 3.3 will pose little problem to even the most busy frontline doctor. However, a systematic approach and more ***TIME*** are required to identify less obvious cases and to determine early complications including hydrocephalus, infarction, giant aneurysms and hematomas which may be associated with SAH.

3.3.1 The Interhemispheric Fissure

The interhemispheric fissure is the home of the anterior communicating artery and anterior cerebral artery aneurysms, the commonest site of aneurysms. Subarachnoid hemorrhage here is characterized by interhemispheric blood or hematoma and not infrequently it ruptures into the ventricle as in Fig. 3.5c.

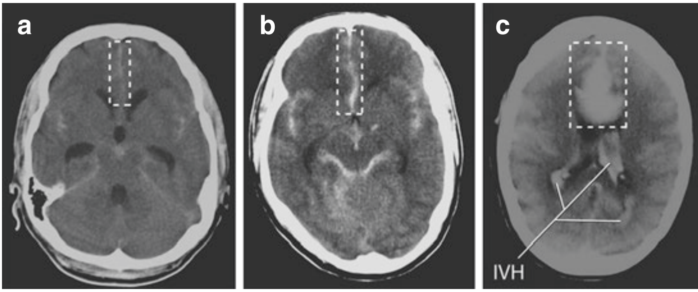


FIGURE 3.5 Non-contrast axial CT scans showing different amounts of blood visible in the interhemispheric fissure (dotted boxes in **a**, **b**, **c**). The idea is to look carefully in this location on all the slices with one intention only—to find blood if present! Note carefully that the quality of the CT scan can vary widely even from the same machine due to differences in brightness of the images as produced for you by the radiographer. The intraventricular hemorrhage (IVH) in image (**c**) is obvious but the overall quality of this image is poor. *If the image quality is unsatisfactory for any reason, then be sure to have a neuroradiologist review the films or have the radiographer repeat them! Can you identify the other locations where blood is seen in this series of scans from three different patients? The Sylvian fissures, third ventricle and ambient cisterns*

3.3.2 The Sylvian Fissures

The sylvian fissures are home to middle cerebral artery aneurysms. It is important to note that the sylvian fissure communicate freely with the central sulcus and other sulci which run to the convexity of the brain as shown by the blood in Fig. 3.6 (compare with Fig. 3.2). Occasionally the blood in the basal part is washed off by the CSF turnover, leaving a streak of blood in the convexity sulci alone. This should be appreciated as possibly coming from an aneurysm.

3.3.3 The Ambient Cisterns

The ambient cisterns surround the midbrain and communicate with the interpeduncular fossa where the circle of Willis

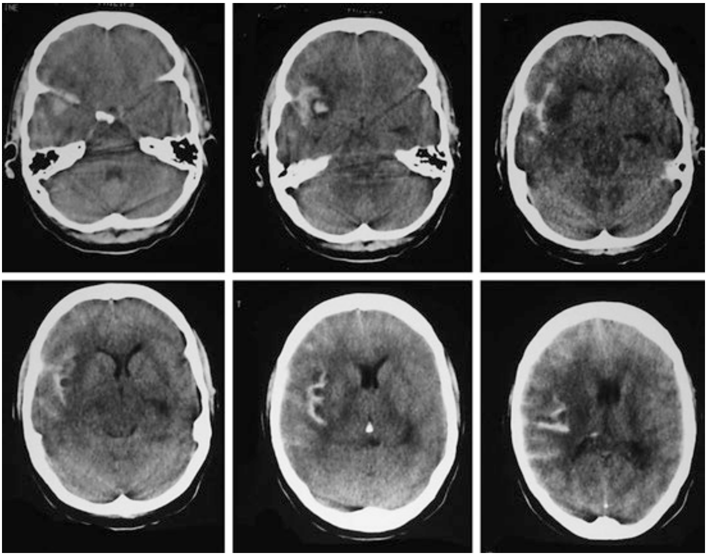


FIGURE 3.6 Non-contrast CT scan showing right sylvian fissure small hematoma and subarachnoid blood. *The important point is that the subarachnoid spaces are barely visible on the opposite side.* In less obvious cases, it is the areas corresponding to where the blood is seen on the right that are scrutinized for any evidence of blood. Can you try finding the CSF spaces on the left corresponding to the spaces where the blood is seen on the right?

is located. Bleeding into this space could come from several places and is easily recognized by the ***loss*** of the dark CSF density around the midbrain. The telltale sign in this area is that the ambient cisterns which are normally hypodense may appear ***iso***dense with brain; that should trigger a focused scrutiny for other evidence of SAH. Of course, if the presence of blood is as obvious as the case in Fig. 3.7b, then the diagnosis is easy.

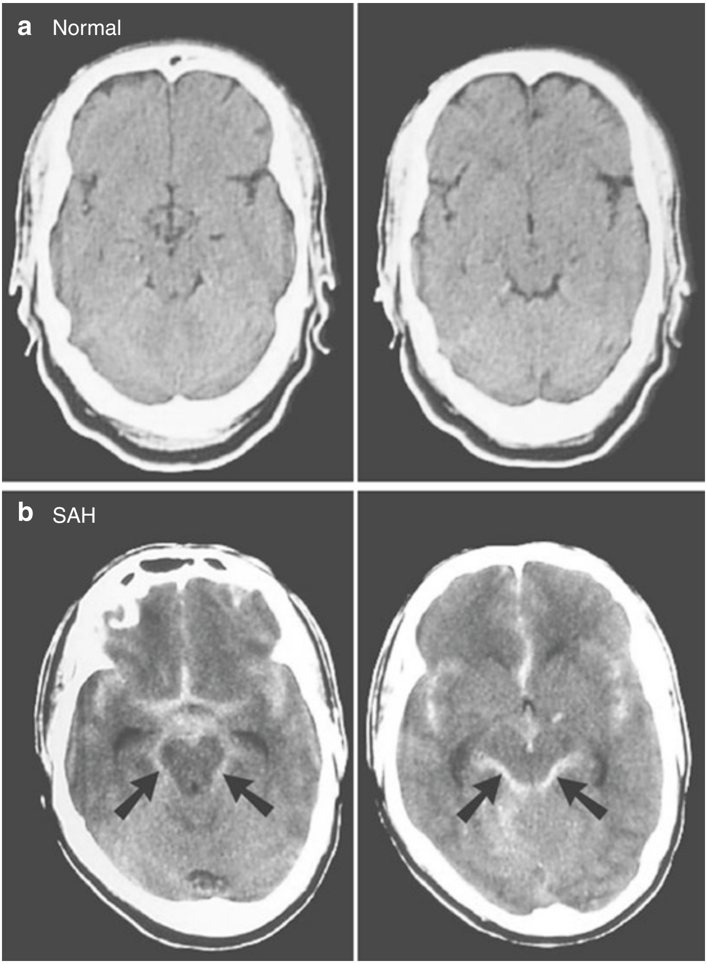


FIGURE 3.7 Normal brain CT scan with normal ambient cisterns with hypodense CSF (**a**) and what they look like in the presence of subarachnoid hemorrhage (black arrows) in the image pair below (**b**). Note that there is widespread blood in the other CSF spaces as well (interhemispheric, sylvian fissure and the suprasellar cisterns)

FIGURE 3.8 Clear example of prepontine hemorrhage (white arrows). However, there are frequent artifacts in the posterior fossa slices of the CT scan making the detection of such a lesion in less obvious cases difficult, hence there is the need for focused scrutiny of this location

3.3.4 Prepontine Cisterns

The prepontine cistern is a very important location to scrutinize for SAH because basilar tip aneurysms make their home here and hyperdense blood from SAH could be easily obscured by the surrounding bone which forms the anterior boundary of this space (Figs. 3.8 and 3.9).

3.4 Associated Features or Complications: The H.I.G.H. of SAH

H.I.G.H. stands for ***H***ydrocephalus, ***I***nfarction, ***G***iant aneurysms and ***H***ematoma.

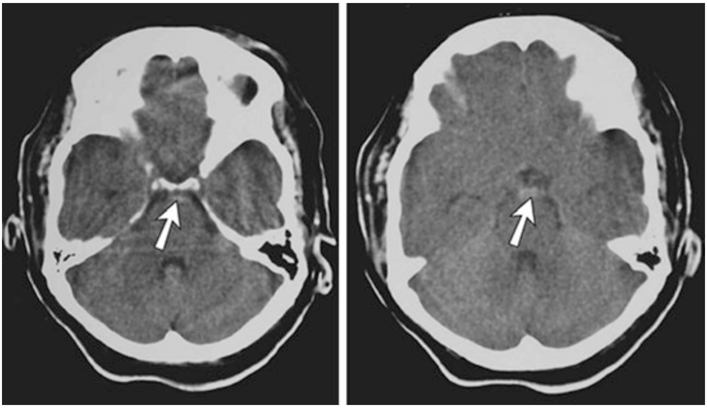


FIGURE 3.9 Shows the CT scan of a 51-year-old hypertensive and diabetic lady with sudden onset severe headache described as the worst headache of her life. She was alert but had neck stiffness and mild photophobia. The small hemorrhage in front of the pons could easily be overlooked unless this area is scrutinized. That it is not an artifact is confirmed by tracing its continuity on contiguous slices. *It is far safer to err on the cautious side and have a more experienced person review the images should you see these appearances on only one slice or suspect they are artifacts!*

3.4.1 Hydrocephalus as a Subtle Sign of SAH

Hydrocephalus (often transient) is a frequent accompaniment of SAH. In mild or early hydrocephalus, the patient often gives a typical history of sudden onset severe headache, a day or more before presentation to hospital. The brain CT scan may show only early hydrocephalus characterized by dilatation of the temporal horns of the lateral ventricles. This should be taken as a strong clue of recent SAH because in the normal brain scan (Fig. 3.10) the temporal horns are usually not visible or barely seen on focused search. However in early hydrocephalus as may occur following SAH, the temporal

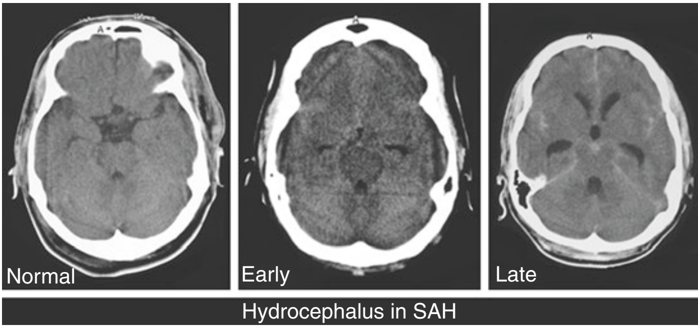


FIGURE 3.10 Axial non-contrast CT scans showing *normal* ventricles and *early* hydrocephalus in a 48 year old female school teacher who gave a 24-h history of sudden severe headache. She had neck stiffness and had vomited twice. The early hydrocephalus is much more easily visible than the increased hyperdensity in the right sylvian fissure and interhemispheric fissure and right ambient cisterns. In the more severe and *late* case of hydrocephalus following SAH, the temporal horns are larger and the third ventricle is rounded with obvious residual SAH visible in the usual locations bilaterally

horns become clearly visible or comparable in size to the frontal horns as seen in Fig. 3.10. In more severe cases the hydrocephalus is obvious with a rounded third ventricle (instead of being slit like) and the temporal horns are obviously dilated (Fig. 3.10). Thus, a suggestive clinical history plus the finding of early hydrocephalus on the CT scan is presumptive evidence of SAH and requires further review of the images by a neuroradiologist. When blood is evident as in Fig. 3.6 (above) the diagnosis is certain, and the next investigation is CT angiography to locate the source of the subarachnoid hemorrhage (Fig. 3.15 below).

Exercise 5 Can you identify 3 CSF spaces with or without blood in this CT scan?

3.4.2 Hydrocephalus as an Acute Emergency

Not infrequently hydrocephalus is *catastrophic* and becomes the immediate cause of death hence the survival of those who get to the CT scanner depends on the immediate appreciation of the CT appearances and quick response of the frontline doctor. In this situation the patient usually suddenly lapses into deep coma requiring respiratory support with clinical evidence of brain stem compromise (coning). The CT scan shows blood filling and dilating the ventricular system (all four ventricles) as well as widespread subarachnoid hemorrhage in the usual locations (Fig. 3.11). It is particularly important to transmit this information to the neurosurgeon as brain specific intervention such as external ventricular drain maybe life saving and may have to be integrated into the early resuscitative effort, following the ABCs of resuscitation.

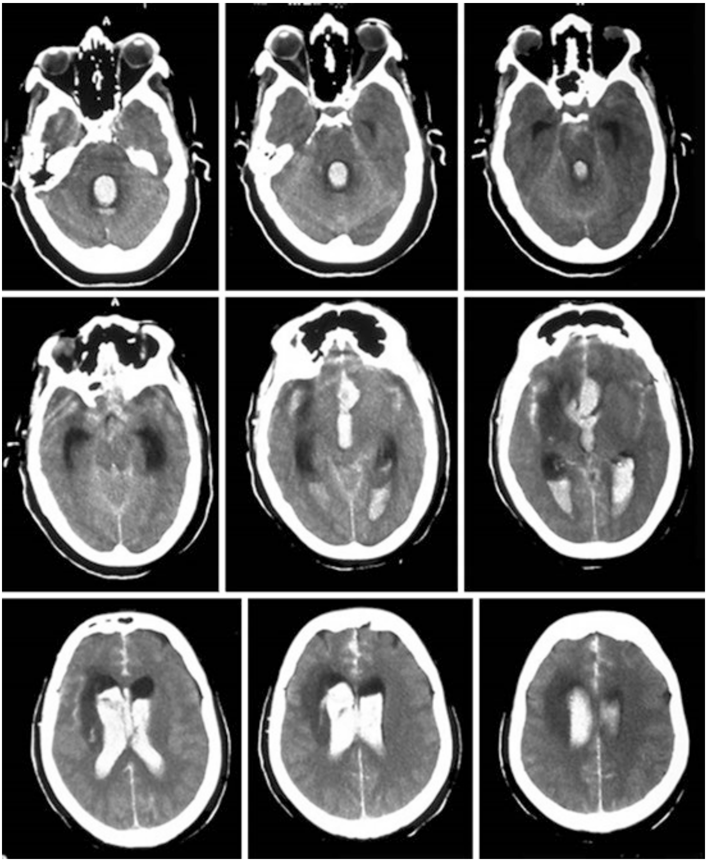
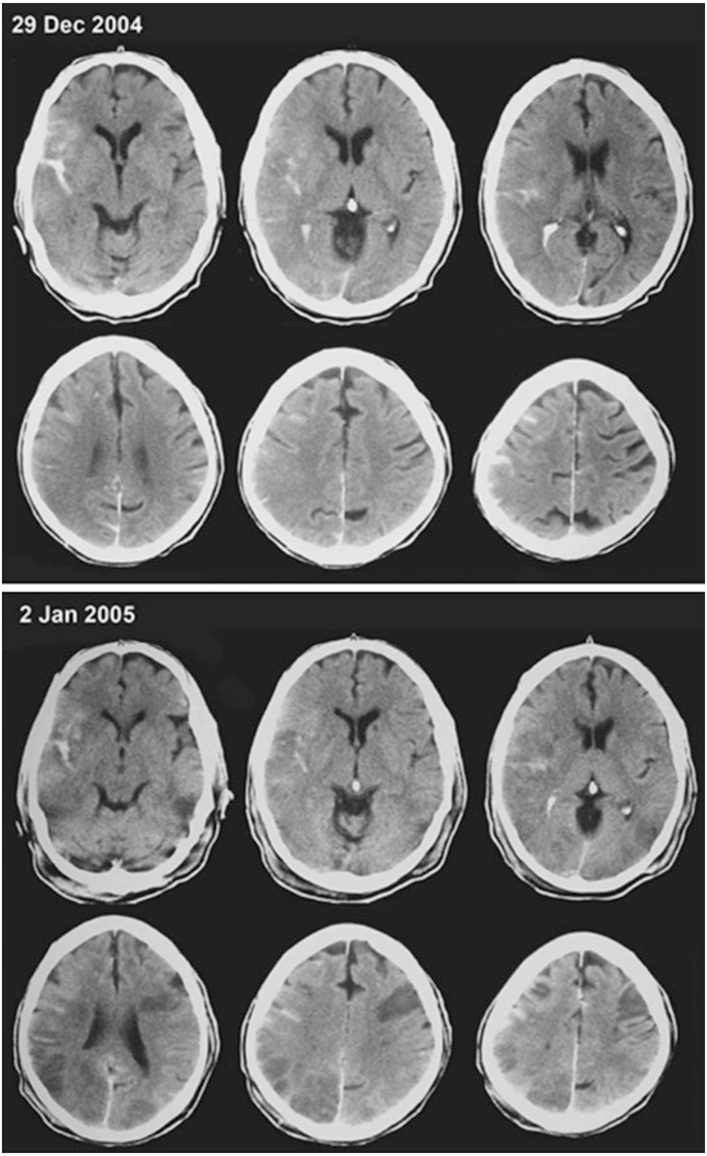


FIGURE 3.11 Non-contrast brain CT scan showing massive intraventricular hemorrhage with hydrocephalus as well as widespread subarachnoid hemorrhage. The patient was aged 45 years and suddenly slumped on top of his wife during intercourse

3.4.3 Infarction

Low densities in the brain parenchyma associated with a recent (≥3 to 10 days) history of SAH when present implies established or imminent infarction or edema of the brain (Fig. 3.12). It occurs following widespread SAH and unlike ischemic stroke with clear margins (see below), the hypoden-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sities in SAH tend to cross vascular boundaries and be more pronounced in the watershed areas i.e. the boundary areas between the blood supply of the anterior cerebral and middle cerebral arteries. This complication which represents vasospasm with ischemia usually occurs after the third day and hence it may be seen in inpatients or patients transferred from other hospitals or in patients who present late especially in parts of the world were CT scans are not readily available.

3.4.4 Giant Aneurysms

Giant or large aneurysms maybe visible on brain CT scan. They exert a lot of mass effect and may precipitate hydrocephalus. The differential diagnosis to consider is a tumor. Aneurysms generally have a smoother and more rounded outline compared to tumors and are often located in the areas where aneurysms are usually found—the suprasellar cistern and the sylvian fissures. In addition, SAH associated with tumors like gliomas, meningioma or pituitary tumors for example, is a very rare occurrence. Therefore, a mass lesion like Fig. 3.13 in association with SAH equals a large aneurysm until proven otherwise and you should act quickly.

Figure 3.12 Initial and follow-up CT scans of a 70-year-old male showing hypodense lesions consistent with watershed infarcts from SAH. He was noticed to have fallen down clutching his head. This case also illustrates the important clinical situation when trauma follows the collapse from SAH. It becomes imperative to determine if the SAH was primary or secondary to trauma. Although a large volume of blood in the basal cisterns often suggest primary (aneurysmal SAH) and blood over the convexity associated with fractures may point to trauma, the distinction may not be clear cut

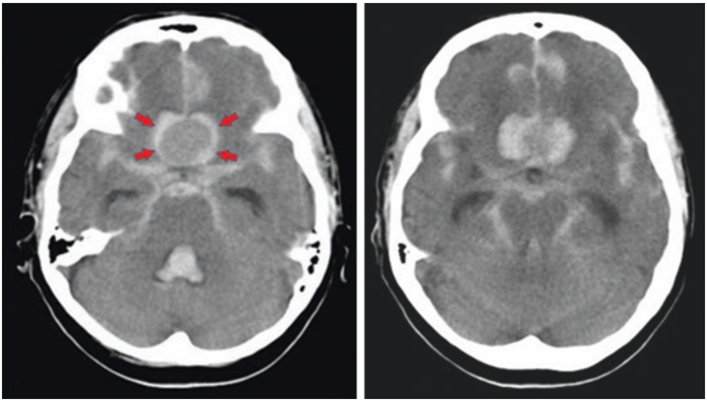

FIGURE 3.13 Brain CT scan showing a giant anterior communicating artery aneurysm. Note the widespread SAH and hydrocephalus. The outline of the aneurysm is made obvious by the blood surrounding the aneurysm wall in the interhemispheric fissure (red arrows)

3.4.5 Hematoma

Subarachnoid hemorrhage associated with intracerebral hematoma also signifies large volume of hemorrhage and the location is often in the temporal lobe (middle cerebral artery aneurysm) or the frontal lobes—interhemispheric hematoma from anterior communicating artery aneurysm. The typical appearance consists of subarachnoid hemorrhage in the usual locations associated with a large hyperdense clot inside the brain proper (Fig. 3.14). The important differential diagnosis here is hypertensive intracerebral hemorrhage which can be distinguished from aneurysmal hemorrhage with hematoma by the classic basal ganglia location of the former (see below) as well as the lack of a significant SAH. The CT appearances of the two types of lesions may occasionally be indistinguishable, but from a practical point of view, both require review by a neurosurgeon.

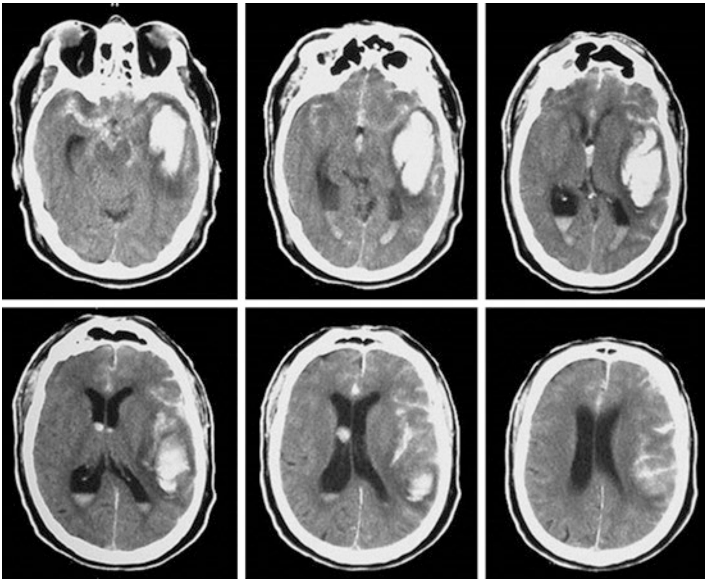

FIGURE 3.14 Non-contrast axial CT brain scan showing a left temporal hematoma and widespread subarachnoid and intraventricular hemorrhage. It is obvious that the epicenter of the hemorrhage is in the left temporal lobe, but there is blood everywhere including the right sylvian fissure which confirms that the subarachnoid hemorrhage is pretty continuous from left to right and around the brain surface

3.4.6 Epilogue on CT Scan for SAH

The table below (Table 3.1) shows the basic approach to identifying SAH on CT scan. The gold standard for detecting aneurysms at present is digital subtraction angiography (Fig. 3.15).

However, practices vary significantly across the world depending on resources and access to appropriate care. In most centers with the appropriate resources, a CT angiogram can be obtained non-invasively to evaluate a suspected aneurysmal mass (Fig. 3.16) or a patient with a history strongly suggestive of subarachnoid hemorrhage but no CT evidence of blood. The role of a properly performed lumbar puncture

Table 3.1 Key steps in looking for SAH

1. Compare left and right
2. Look for SAH in the sulci, remember blood will settle into the sulci not on the gyri.
3. Look in the usual locations sylvian fissure, interhemispheric fissure, basal and prepontine cisterns.
4. Look for associated features like hydrocephalus, infarction, giant aneurysms and hematoma.
5. Above ALL—remember the clinical history is your best clue!

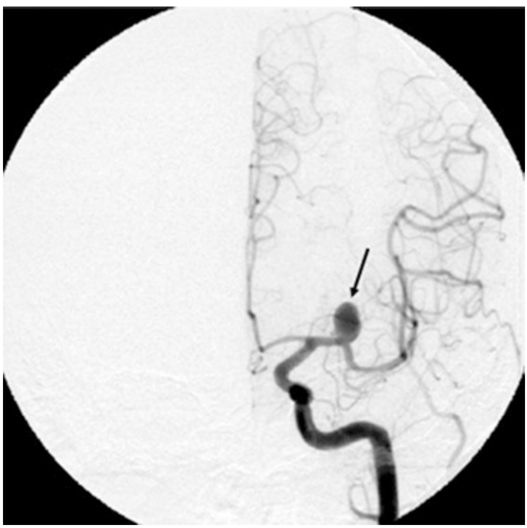

Figure 3.15 Digital subtraction angiogram showing a left middle cerebral artery aneurysm (black arrow)

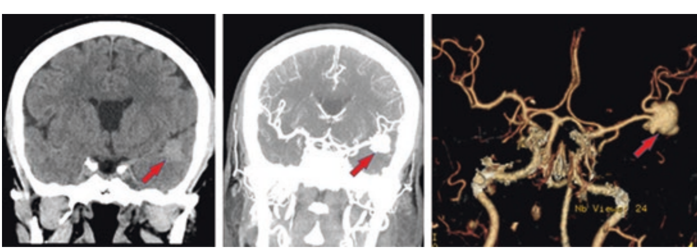

Figure 3.16 Non-contrast CT scan and CT angiogram showing left MCA aneurysm (red arrow)

(previously common) is now mostly limited to places lacking access to advanced imaging capabilities.

Therefore, with the increased experience with CT angiogram and MR angiography, the threshold for these tests is much lower and their sensitivity and specificity now approach digital subtraction angiography in most centers with these advanced imaging capabilities (Table 3.1).

3.5 Spontaneous Intracerebral Hematoma

Spontaneous intracerebral hemorrhage occurs inside the brain substance proper (for instance inside the parenchyma of the brain) as opposed to subarachnoid hemorrhage which bleeds into the subarachnoid space. It is called spontaneous to distinguish it from traumatic intracerebral hematoma. It is noteworthy to point out that trauma is the commonest cause of bleeding inside the head. Thankfully the vast majority of traumatic bleeds inside the head are small but the spontaneous hematomas tend to be larger. It is helpful to learn that intracerebral hematoma also has special locations which together with the etiology gives it a unique identity. Whereas rebleed is the principal concern in the majority of cases of subarachnoid hemorrhage, the principal concern in intracerebral hematoma is the mass effect and functional damage. Whereas the *good grade* SAH patient may expect to live a normal life with *appropriate* successful treatment, the patient with a small internal capsule hemorrhage maybe hemiplegic for life with little recourse to surgery. While clinically significant intracerebral hematomas are obvious on the CT scan, subarachnoid hemorrhage maybe difficult to detect yet the underlying aneurysm remain lethal should it bleed again. In addition, most patients with significant intracerebral hematoma except few polar hemorrhages will have significant findings on neurological examination but up to 50% of patients with SAH may show no focal neurologic finding except the

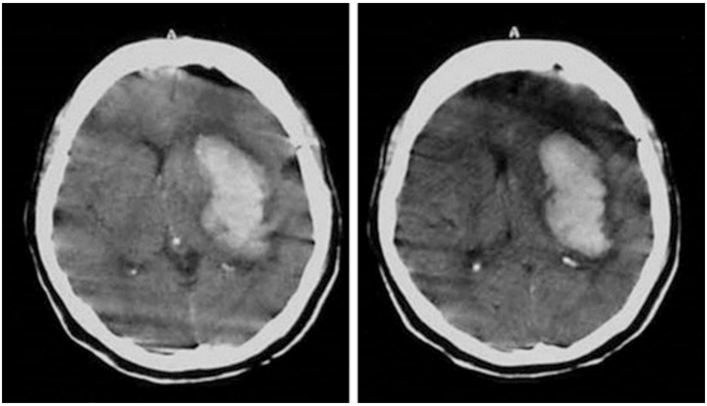

Figure 3.17 Non-contrast axial CT scan of a 31-year-old male with sudden right hemiplegia and altered level of consciousness, showing a large left basal ganglia/internal capsular hemorrhage. Note the movement artifacts as the patient was restless and not fully co-operative. The lesion is obvious in spite of the artifacts. The quality of the CT image may vary from place to place depending on resources, but the rule of thumb is that "only the best image is good enough for interpretation in order not to miss a small abnormality"!

headache that brought them to the emergency care physician! Therefore, in this chapter, the emphasis has been on detection of SAH without trivializing the importance of intracerebral hematomas (Fig. 3.17).

3.6 Usual Locations and Etiology

Spontaneous intracerebral hematoma is often the result of uncontrolled hypertension or amyloid angiopathy. The lenticulostriate vessels (Fig. 3.18) arise from the middle cerebral artery bringing relatively high hydrostatic pressure from the carotid to the internal capsule, basal ganglia and thalamus. These areas are therefore prone to hypertensive hemorrhage and are the usual locations although a large hemorrhage could rupture into the ventricles (Fig. 3.19) and confuse the beginner in neuroradiology or emergency medicine.

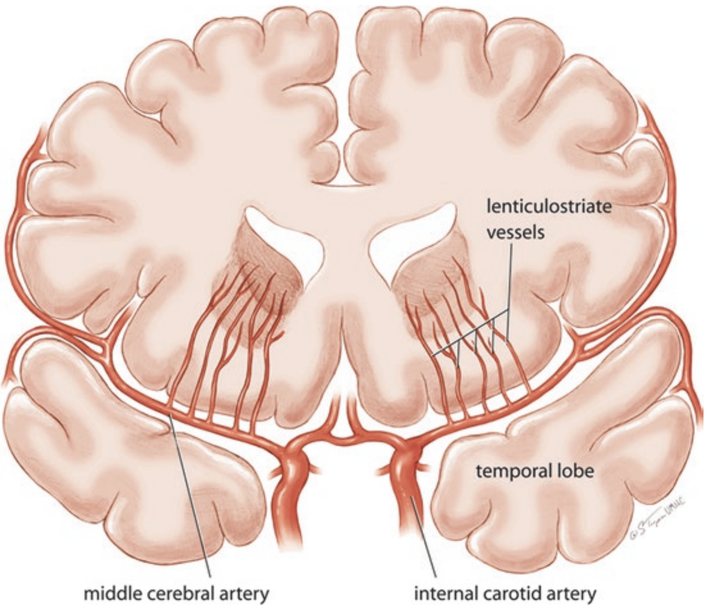

FIGURE 3.18 Drawing of the cerebral vessels with part of the brain removed to show the lenticulostriate vessels that are responsible for hemorrhage in hypertension (and infarction in ischemic stroke {see below})

Spontaneous intracerebral hematomas maybe obvious on the CT scan, but telling someone else on the phone or in written form, requires a clear description of the size and location of the clot. Therefore, a basic understanding of few key structures in the brain (Fig. 3.20) is essential to understanding the importance of an intracerebral hematoma.

3.7 Basic CT Scan Internal Landmarks

The anatomy of the brain can be viewed simplistically as a mushroom or umbrella in which the stem is formed by the brain stem and the cerebral hemispheres represent the cap of the umbrella. The brain stem consists of the medulla oblongata

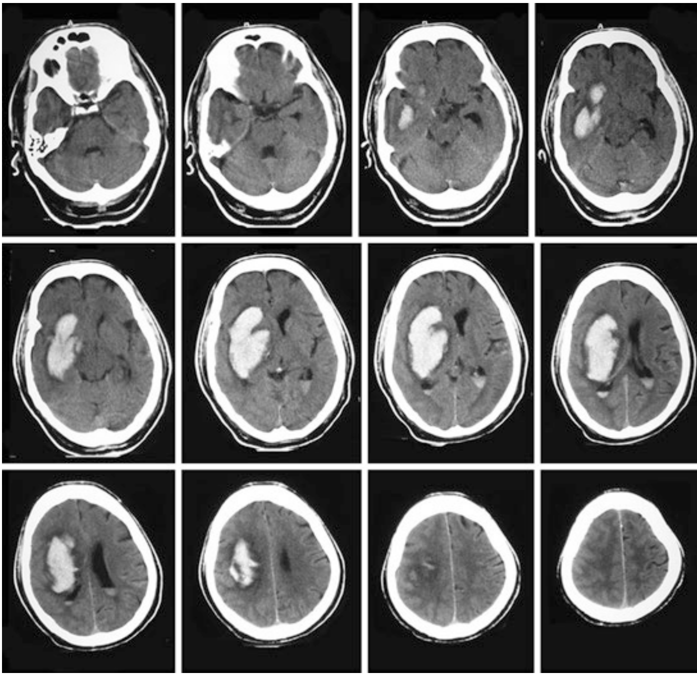

FIGURE 3.19 Non-contrast CT scan of a 60-year-old male who developed sudden left hemiplegia and headache but was alert and orientated. It shows a large left internal capsular hemorrhage which has ruptured into the ventricles. Note that, in spite of the size of the intracerebral hematoma there is very little SAH. Compare with Fig. 3.14 which is aneurysmal SAH with an intracerebral hematoma

(no. 1 in Fig. 3.20), Pons (no. 2 in Fig. 3.20) and the midbrain (no. 3 in Fig. 3.20). The pons is easily identified as the quadrangular mass in front of the fourth ventricle often with the basilar artery visible in front of it (white arrow in images E, Fig. 3.20). Thus, as soon as you identify the fourth ventricle, the pons is in front and the medulla is below the pons and the midbrain sits atop the pons as shown in the sagittal image (Fig. 3.20 image I). The lazy “V” (dotted white lines) facing laterally (Fig. 3.20h) marks the position of the internal capsule, a key structure in this part of the brain. The caudate nucleus

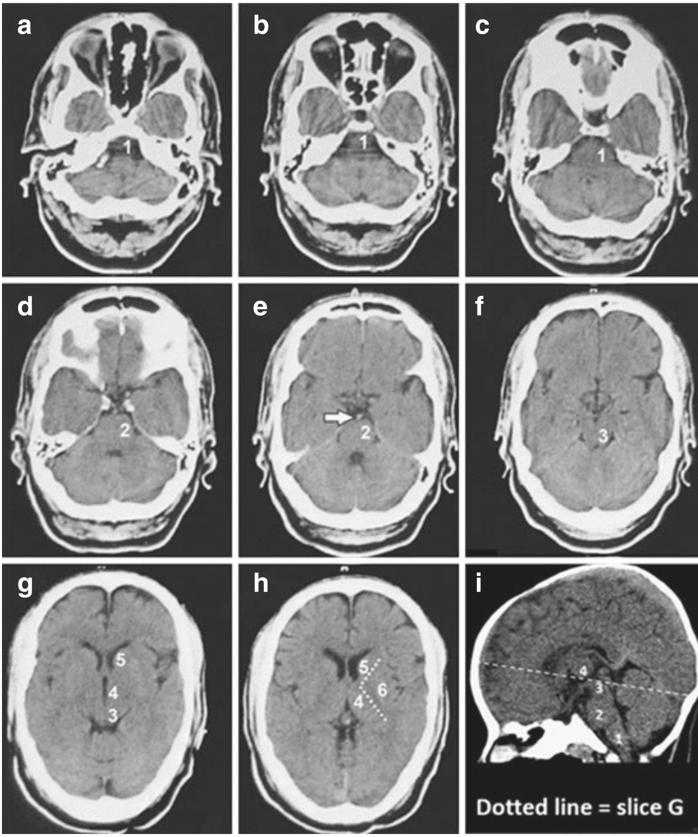

FIGURE 3.20 Non-contrast CT scan showing landmark structures numbered from 1 to 6 and the individual axial images are labeled from **a** to **h** and one sagittal image labelled **i**

(no. 5 in Fig. 3.20) and the thalamus (no. 4 in Fig. 3.20) are medial to the internal capsule whereas the lentiform nucleus consisting of the globus pallidus and putamen sit inside the "V" (no. 6 in Fig. 3.20) and are lateral to the internal capsule. Hence close scrutiny of Fig. 3.19 will show that the hematoma started in the lentiform nucleus and ruptured into the ventricles. The caudate nucleus, thalamus, internal capsule and the

lentiform nucleus represent the important areas supplied by the lenticulostriate arteries illustrated in Fig. 3.18, hence this area is the typical location of hypertensive hemorrhage (Fig. 3.19). Similarly, ischemic stroke affects the same areas frequently.

As I mentioned in chapter one, understanding the CSF spaces is key to interpreting a brain CT scan. Thus, the fourth ventricle is an important landmark: the pons is in front of it and behind the fourth ventricle is the ***cerebellum*** (Fig. 3.20). Hemorrhage into the cerebellum (Fig. 3.21) or pons (if large enough) may compress the fourth ventricle or rupture into the fourth ventricle leading to hydrocephalus. Therefore, if you see a hemorrhage (blood clot) in the cerebellum or pons, you must immediately ask yourself the question, is there hydrocephalus.

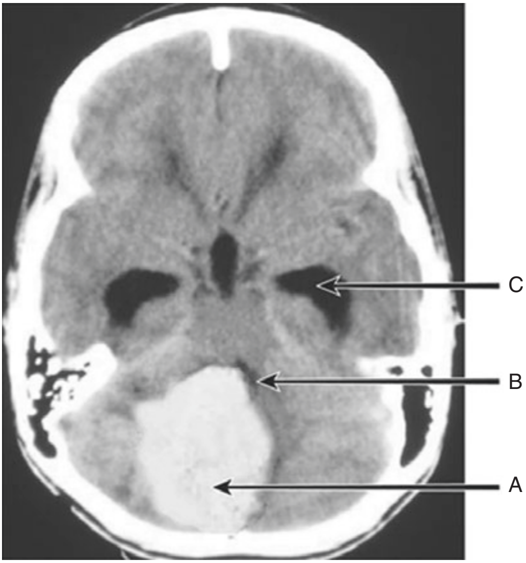

FIGURE 3.21 A non-contrast CT scan showing a large cerebellar hematoma (A) causing almost complete compression of the fourth ventricle (B) with obvious hydrocephalus seen in the dilated temporal horns (C)

Spontaneous hemorrhages in the cerebral hemispheres could arise from several causes including hypertension, amyloid angiopathy and arteriovenous malformations and tumors. Of these the AVMs (Fig. 3.22) are very important because of the risk of recurrent hemorrhage and their propensity to occur in the young patient. The clot often appears close to the brain surface (Fig. 3.23a) and there may be associated subarachnoid hemorrhage. *It is obvious that the site and size of an intracerebral hematoma are important in determining the clinical effects of an intracerebral hematoma and that brain shifts portend catastrophic decline in clinical condition.* Of course, it goes without saying that the side of the hemisphere: left or right is important and although the shape may not tell the beginner much, tumoral hemorrhages tend to give a clue in their density (Fig. 3.23b).

Clinical vignette: *A 5-year-old girl fell and hit her head sustaining a skull fracture and scalp hematoma. She was seen*

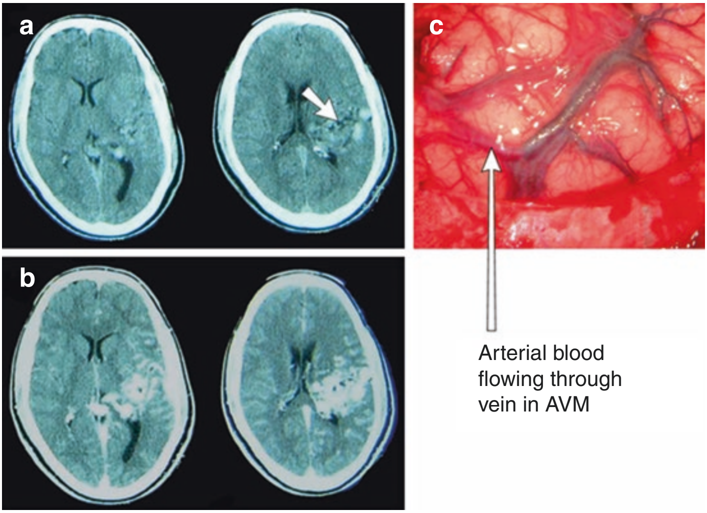

FIGURE 3.22 Composite picture of CT scan of an unruptured AVM (pre-contrast {**a**} and post contrast {**b**}) with an operative photograph (**c**) showing arterialized veins and the junction of venous and arterial blood

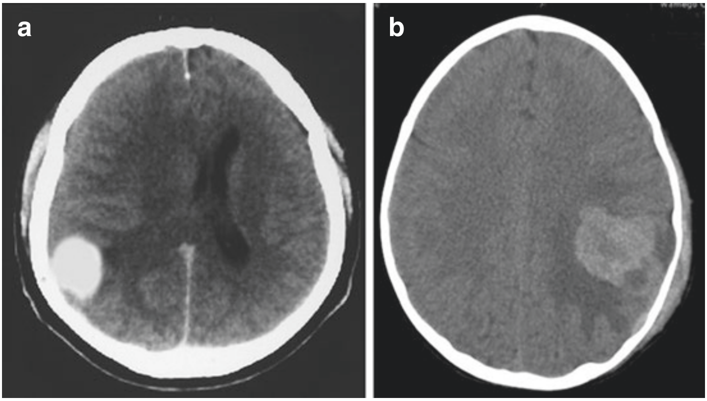

FIGURE 3.23 Non-contrast CT scan showing right parietal intracerebral hematoma secondary to an AVM (**a**). Note the surface location and the swelling in the underlying hemisphere. Compare with the CT scan of the 5-year-old who fell down and was thought to have a contusion of the left parietal lobe (**b**). The surrounding oedema and the dull greyish heterogenous appearance were significant red flags to suggest that this was not just an acute clot from a fall but more likely to be a tumor

in the emergency room and a CT scan was obtained (Fig. 3.23b). *The CT scan was reported as showing a contusion and the patient was discharged home. I reviewed the CT scan the next morning and called the parents at home and told them to bring the child back to the hospital and prepare for admission and that we will obtain an MRI scan. Can you tell the difference between the tumor and the intracerebral hemorrhages we have seen so far? Compare* Fig. 3.23a, b. *The tumor often appears as a more heterogenous hyperdensity and not infrequently with surrounding edema. She had the tumor removed the next day and the histology was astroblastoma. Therefore, paying attention to the density of the hematomas you see in your day to day practice is important and you can certainly describe them in terms of the five S's (site, size, shifts, side and shape) as described for traumatic hematoma.*

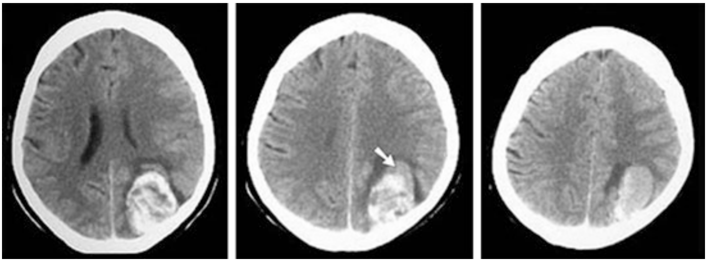

FIGURE 3.24 Non-contrast CT scan showing left parietal intracerebral hemorrhage into a tumor. Note the different density (white arrow) and the surrounding low density which represents edema

Although hemorrhage into a tumor is far less common, the CT scan may show a double density (white arrow in Fig. 3.24) different from the hematoma and also the presence of edema (low density) around the clot. *Whereas these are not pathognomonic features of tumor hemorrhage, they should point to further scrutiny of the scan.*

3.8 Ischemic Stroke (Cerebral Infarction)

It is convenient to start by reviewing Fig. 3.25 which illustrates the fact that the lenticulostriate arteries supply the basal ganglia and internal capsule. This area is commonly involved in stroke, be it hemorrhagic or thromboembolic. *The key principle behind successful use of the CT scan in dealing with ischemic stroke is KNOWING WHERE TO LOOK! AND WHAT TO LOOK FOR! And WHEN TO LOOK!*

Ischemic stroke will show very little signs on the CT scan within the first 2–3 h of the ictus (event) (Fig. 3.26), depending on the area involved and the presence or absence of anastomotic collaterals and the quality of the CT scan used. *The golden rule with stroke as with most of emergency neurosurgery or neurology is that, the clinical symptoms reign supreme.*

Therefore, for the patient in Fig. 3.26 with a right hemiplegia, the conclusion following that first CT scan is that it is too

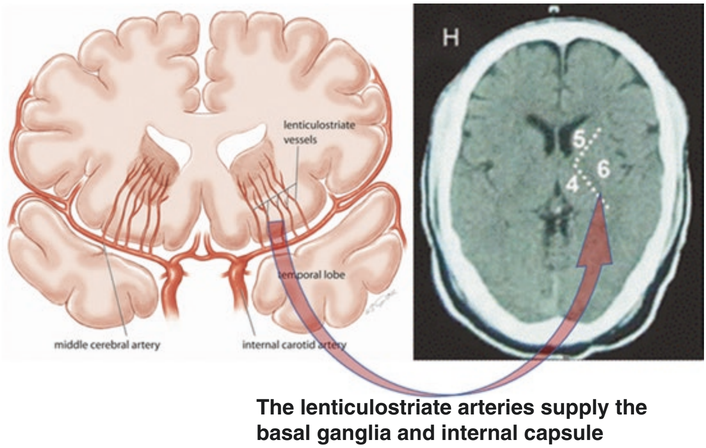

FIGURE 3.25 Simplified schema of blood supply to the internal capsule and basal ganglia

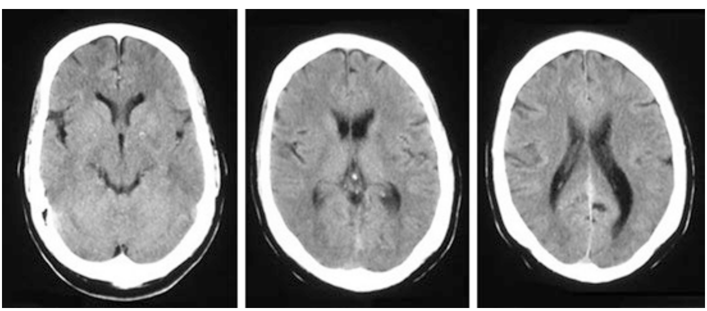

FIGURE 3.26 Non-contrast CT scan of a 61-year-old male with sudden onset right hemiplegia two and a half hours prior to the CT scan. He is diabetic and hypertensive. *Given the history most experienced radiologists will identify the subtle differences but it may seem completely normal to a beginner. The CT findings are often only as important as the question it was intended to answer! What was/were the clinical question(s) in requesting a CT scan here? Answer: 1. To see if there was hemorrhage. 2. To see if there is a low-density signifying infarct. 3. Look for any other cause of hemiplegia, e.g. tumor*

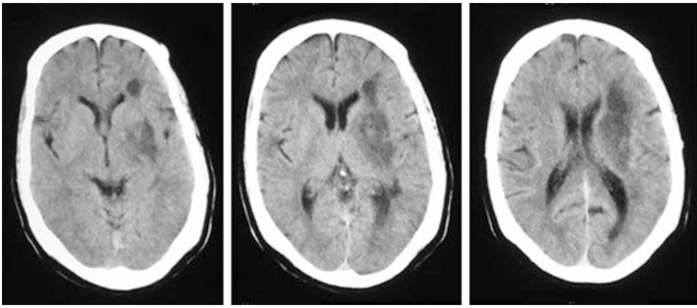

FIGURE 3.27 Non-contrast CT scan of the same patient as in Fig. 3.26 showing the now obvious left basal ganglia infarct (low density) about 1 week after the oneset of symptoms

early to see obvious changes on the CT scan, so a follow-up imaging (or advanced imaging) is needed and the patient gets referred to a neurologist or stroke physician promptly. It should not be seen as a normal scan and the patient's treatment delayed *as a consequence of lack of pace*. In fact, it is a common reason in many centers to carry out the emergency CT scan in thrombotic CVA simply to confirm the absence of a mature infarct or hemorrhage prior to anticoagulation or thrombolysis or thrombectomy. What follows therefore is one approach to describing a thromboembolic CVA bearing in mind the time dependent nature of the CT appearances (Fig. 3.27).

Ischemic stroke can be described with the acronym THOSE to signify the major events occurring.

3.9 T Stands for the Territory: The Vascular Territory

Because there is very little collateral circulation in the brain, thrombosis in distal arteries often leads to infarction in the area supplied by that artery. This leads to well demarcated zones of infarction as in Fig. 3.27, that is characteristic of the supplying vessel (lenticulostriate vessels). Another common example is the middle cerebral artery (Fig. 3.28).

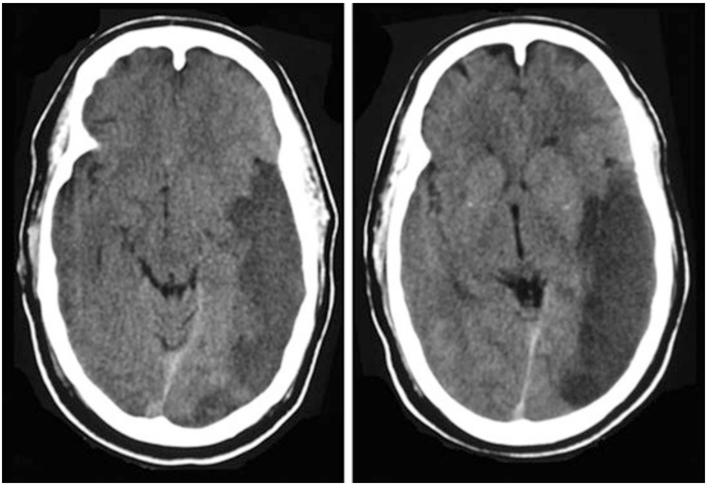

FIGURE 3.28 CT scan showing low density from left middle cerebral artery posterior division infarct

3.10 H Stands for Hypodensity

The basic appearance of an infarct on CT scan is a hypodense lesion often with clear margins. However as seen between Figs. 3.26 and 3.27, the hypodensity does take up to 6–8 h to appear and a clear margin such as is illustrated in Fig. 3.28 may not be obvious for days. Of course, with the latest generation of CT scan machines, perfusion CT scan will invariably show up the ischemic focus well before the appearance of low density on conventional CT. Figure 3.29 shows a middle cerebral artery infarct at 3 and 6 h after the ictus. Can you convince yourself about the low density?

3.11 O Stands for Oedema

The O represents a vital conceptual link between the H and the S. The hypodensity seen on CT scan actually represents ***oedema***—cytotoxic oedema that starts promptly

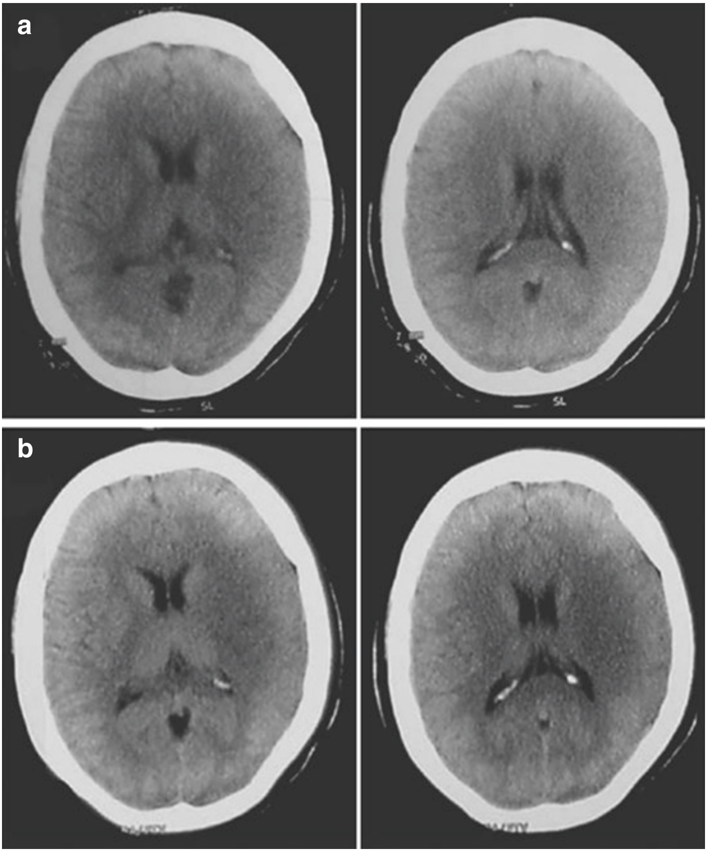

FIGURE 3.29 Non-contrast CT scans at 3 h (**a**) and 6 h (**b**) of a 40-year-old lady who presented with acute onset hemiplegia while cooking dinner in the kitchen. Can you tell which side has the low density? Don't forget the principles of comparing left and right focusing on the 'usual suspect' areas for infarction. Answer: Left side

following the occlusion of the artery. The oedema leads to swelling of the cells with consequent *sulcal effacement* and brain *shift*. The increase fluid leads to the low density (Fig. 3.30).

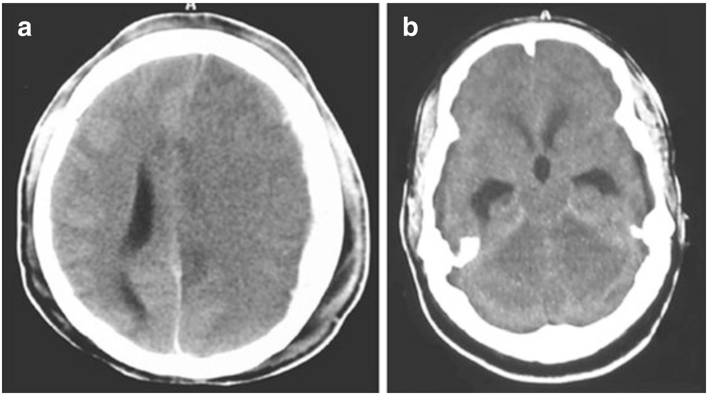

FIGURE 3.30 Non-contrast CT scan showing a massive left internal carotid territory infarct with swelling and midline shift (**a**) and an acute cerebellar infarct with hydrocephalus (**b**)

3.12 S Stands for Swelling and Shifts

Brain shifts occur as the oedematous infarct enlarges squashing the surrounding normal brain against the skull and away from the core of the infarct causing herniation and midline shifts in severe cases. Swelling in the posterior fossa often leads to hydrocephalus Fig. 3.30b).

3.13 E Stands for Evolution

The infarct must always be seen as an evolving lesion often with time dependent consequences. The common outcome is for the swelling to resolve and the necrotic brain is phagocytosed and surrounding ischemic areas undergoes apoptosis leaving behind a permanent low density on the CT as in Fig. 3.28. The other path of evolution is a hemorrhagic conversion which is illustrated (Fig. 3.31). *Acutely therefore, the swelling can cause hydrocephalus, herniation or other catastrophic change that maybe immediately fatal hence the last thing you look for on the CT scan is for any of these complications of the CVA.*

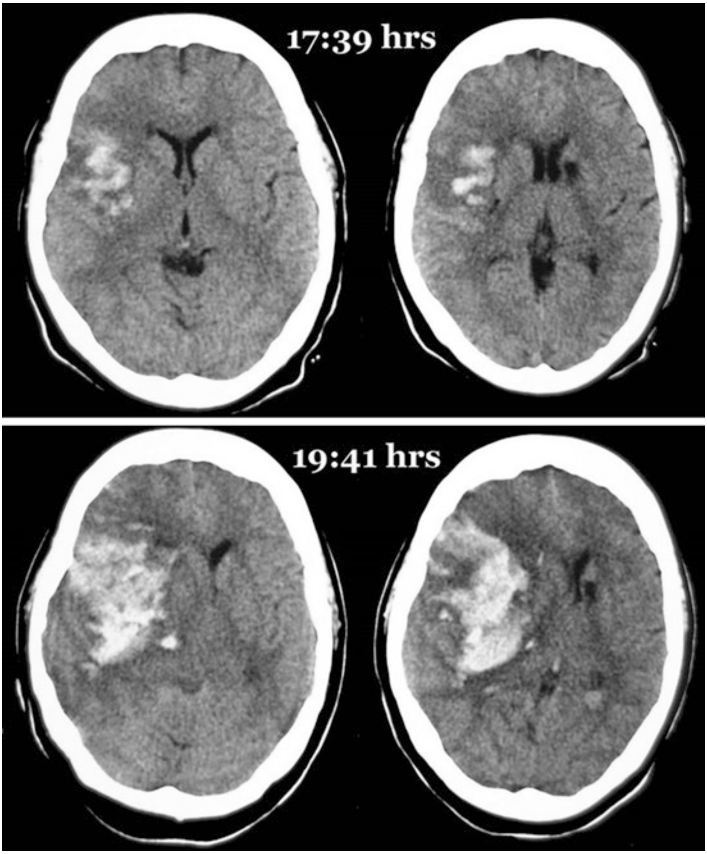

FIGURE 3.31 Non-contrast CT scan of a 60-year-old lady with sudden left hemiplegia who had thrombolysis. Immediate CT scan prior to thrombolysis was unremarkable (not shown). Six hours following thrombolysis the CT scan at 17:39 h was obtained for increased drowsiness. Two hours later, large increase in the size of the clot is evident, *this hemorrhagic conversion can occur with or without thrombolysis*

Although this chapter has summarized this very complex area of neuroimaging it is hoped that some understanding of the basic principles and relevant attitudes can be cultivated

from the approach outlined here. *The golden rule which is worth repeating here is that—the CT scan is only an adjunct to the clinical assessment and not the main source of management decisions!*

In modern day stroke medicine, the slogan “time is brain” is relevant therefore be guided more by the clinical history, but your clear description of the CT scan findings will help the specialist make the relevant decision while enroute to seeing the patient.

Chapter 4
Hydrocephalus

4.1 Introduction

The basic approach to all hydrocephalus is the same: you have to make a judgement whether the size of the ventricles is 'normal' or not, for the ***individual*** *patient.* However, two broad groups of patients can be identified when looking for hydrocephalus in a brain CT scan in everyday clinical practice. The first group of patients are those whose hydrocephalus had ***already*** been ***diagnosed*** (hence they may have previous scans to compare with) and the second group are those patients that have had ***no previous imaging before***. We will consider the second group first. Ventricular enlargement when gross is very easy to recognize on the CT scan (Fig. 4.1a) ***but the key question is whether it is under high pressure or not because hydrocephalus technically is ventriculomegaly associated with raised intracranial pressure.***

It would have been nice if all cases of hydrocephalus were this obvious Fig. 4.1a; however, there are a few basic principles which can be applied to make most cases as obvious as this one. The first important clue is to grasp the layout of the ventricles and the pathway of CSF flow and hence the ***sites prone to obstruction*** (Fig. 4.2).

U. Igbaseimokumo, *Brain CT Scans in Clinical Practice*,
In Clinical Practice, https://doi.org/10.1007/978-3-030-14828-7_4

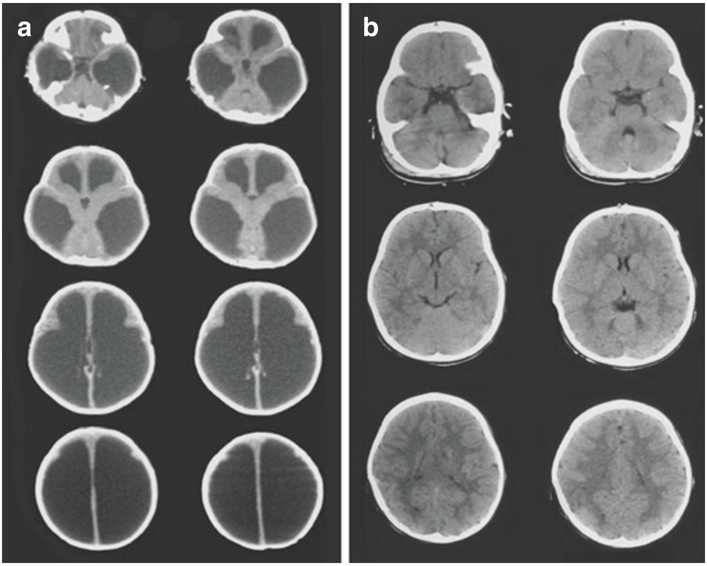

FIGURE 4.1 Non-contrast CT scan of an infant with massive hydrocephalus with little cortical mantle (**a**). Note that in the normal CT scan (**b**), the third ventricle is slit like and the temporal horns are not easily seen at all and you *can* see the Sylvian fissure easily despite the large cortical mantle compared to (**a**) where the Sylvian fissure and the sulci are effaced (squashed up)

The lateral ventricle Fig. 4.3 consists of frontal horn (F), the body (B), occipital horn (O) and the temporal horn (T). Each hemisphere (half) of the brain has a lateral ventricle.

A careful review of Fig. 4.3 will show that the ***bodies*** of the two lateral ventricles are only separated by a thin membrane the *septum pellucidum,* so they practically touch in the midline. The third ventricle, cerebral aqueduct of Sylvius and the fourth ventricle are not paired but located in the midline leaving the final shape of the ventricles like the drawing in Fig. 4.4, which also illustrates the direction of CSF flow.

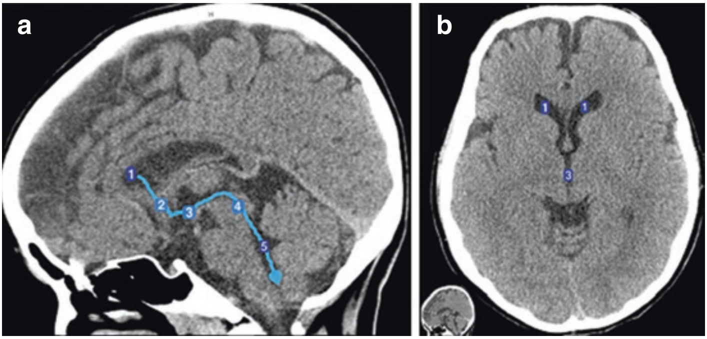

FIGURE 4.2 (**a**) Sagittal view of a non-contrast CT scan showing the path of the CSF from the lateral ventricle (1) passing via the foramen of Munro (2) and entering the little slit like third ventricle (3) and from thence through the Aqueduct of Sylvius (4) to reach the final enlargement in the ventricular system, the fourth ventricle (5). The ventricles can be likened to a cave inside the brain which contains water that flows from 1 to 5 and out through the foramen of Magendie. (Heart shaped arrow tip indicating that the fluid eventually returns to the heart.) (**b**) Is an axial view of a non-contrast CT scan of the brain showing how the frontal horns (1) of the lateral ventricles pass through the foramen of Munro to reach the third ventricle (3)

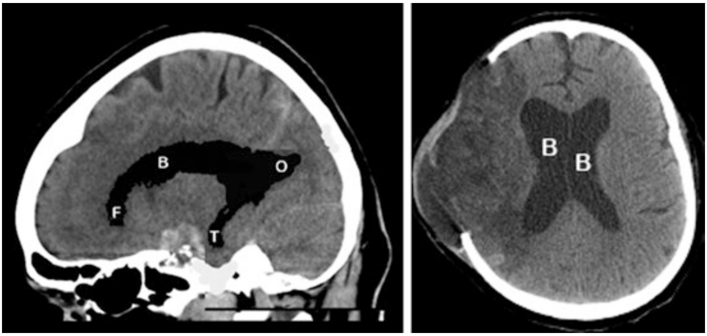

FIGURE 4.3 The lateral ventricle of the brain showing frontal horn (F), the body (B), occipital horn (O) and the temporal horn (T). The point where the body of the lateral ventricle meets the occipital horn and the temporal horn is called the trigone and imparts a triangular appearance to the back end of the lateral ventricle

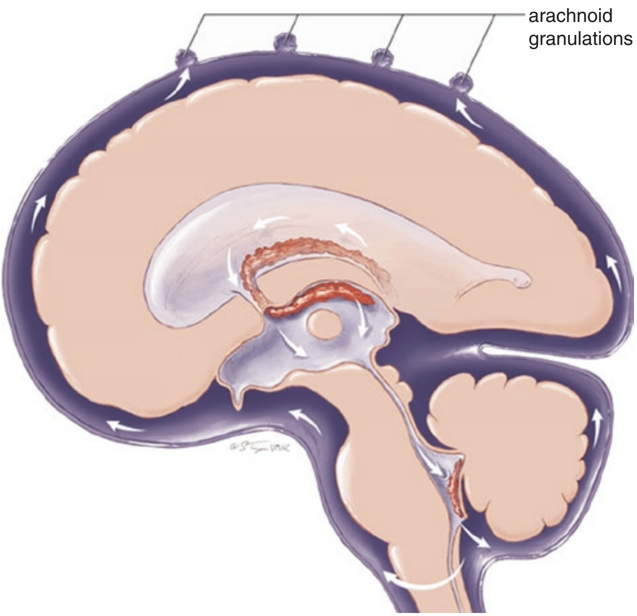

FIGURE 4.4 Model of ventricular system and CSF flow. Note particularly that CSF is produced as an ultrafiltrate of plasma in the choroid plexus located in the lateral, third and fourth ventricles. CSF leaves the ventricular system through the foramen of Magendie (midline inferiorly) and the foramina of Luschka in either lateral angle of the fourth ventricle. From here the CSF enters the subarachnoid space at the base of the skull distributing to the lumbar sac and also flows from the base towards the vertex of the brain where it is absorbed back into the blood at the arachnoid granulations. When hydrocephalus is the result of obstruction of the intraventricular CSF pathways then it is called ***obstructive hydrocephalus***. On the other hand, if the CSF actually leaves the foramina of Luschka and Magendie and absorption is defective at the arachnoid villi in the subarachnoid space, then the hydrocephalus is called ***communicating:*** for instance, there is communication with the subarachnoid space. The importance of this distinction is that obstructive hydrocephalus develops relatively acutely due to the limited compliance from the ventricles. However, once the CSF communicates with the subarachnoid space the compliance is greater and the onset of symptoms of hydrocephalus is more gradual. *In general, the severity and rapidity of onset of symptoms is related to whether there is complete rapid obstruction or a slow gradual partial obstruction. But enlarged ventricles always call for detailed scrutiny by a more senior staff especially if a shunt is in place*

4.2 The Temporal Horns and Third Ventricle in Early Hydrocephalus

Not all cases of hydrocephalus are like Fig. 4.1a that are self evident as soon as you look at the CT scan. Determining the presence of hydrocephalus in less obvious cases therefore requires a systematic approach and the first important clue to early hydrocephalus is enlargement of the temporal horns. Because the temporal horns are only barely visible (if at all) in the normal scan, their ready visualization is a cue to search for other evidence of ventricular enlargement. Figure 4.5 shows temporal horn enlargement as evidence of early hydrocephalus. Look for temporal horns in the slices near the base of the skull in the temporal lobe!

The next important clue is that the third ventricle which normally presents a narrow slit like appearance (Fig. 4.6a)

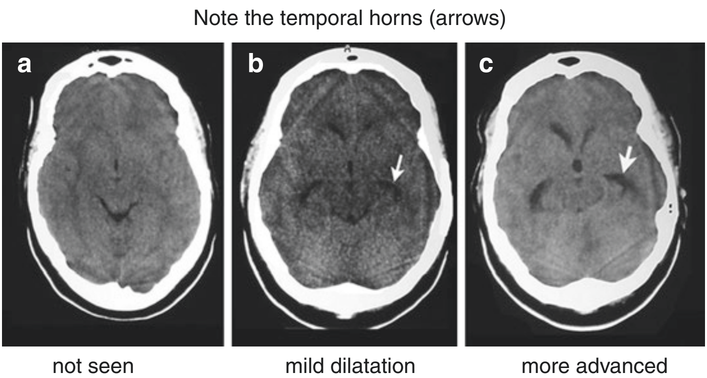

Figure 4.5 This figure illustrates increasing degrees of temporal horn dilatation in the same patient, a 40-year-old female school teacher with normal ventricles when the temporal horns were virtually invisible (**a**) and when she had early dilatation of the temporal horns due to subarachnoid hemorrhage (**b**). The final image (**c**) shows the same lady's CT scan when she developed more severe hydrocephalus due to cerebellar infarction. The significance of mild degrees of ventricular dilatation is often evident when considered with the clinical history or *previous films as in this case*. Note that the temporal horns are visible on both sides in (**b**, **c**)

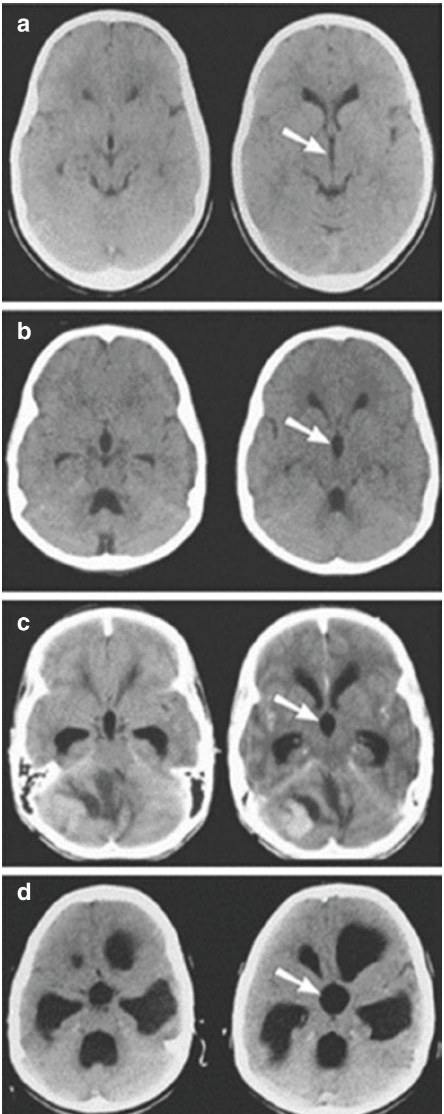

FIGURE 4.6 Non-contrast CT scans showing different degrees of hydrocephalus: (**a**) normal, (**b**) mild hydrocephalus, (**c**) moderately severe hydrocephalus, (**d**) gross hydrocephalus (see text)

changes to an oval shape and in late cases to a frankly rounded third ventricle indicating severe hydrocephalus (Fig. 4.6d). Thus, enlargement of the third ventricle is the second reliable sign of active hydrocephalus in the CT scan.

4.3 Effacement of the Sulci

In addition to the above two important features, careful examination of the CT scans in Figs. 4.7 and 4.8 will show that the sulci are readily visible in Fig. 4.7 in spite of the enlarged ventricles. But in Fig. 4.8 only the large ventricles are clearly visible, and the sulci are completely indiscernible. As the ventricles enlarge with CSF under pressure, the brain is squeezed with the result that the gyri come together and empty the subarachnoid spaces (sulci) of CSF (and the sulci are said to be effaced—for instance not visible on the CT scan). This is

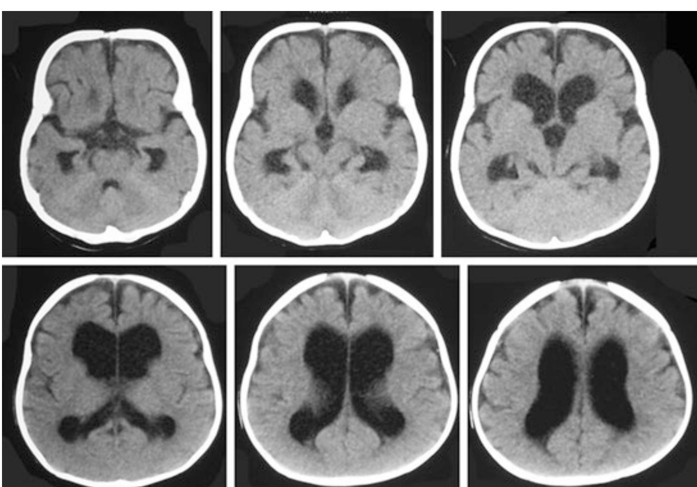

FIGURE 4.7 Non-contrast brain CT scan of an infant showing enlarged ventricles and prominent sulci suggesting some degree of cerebral atrophy. Note in particular that the subarachnoid spaces in the Sylvian fissures and over the frontal lobes are readily seen (compare with Fig. 4.8)

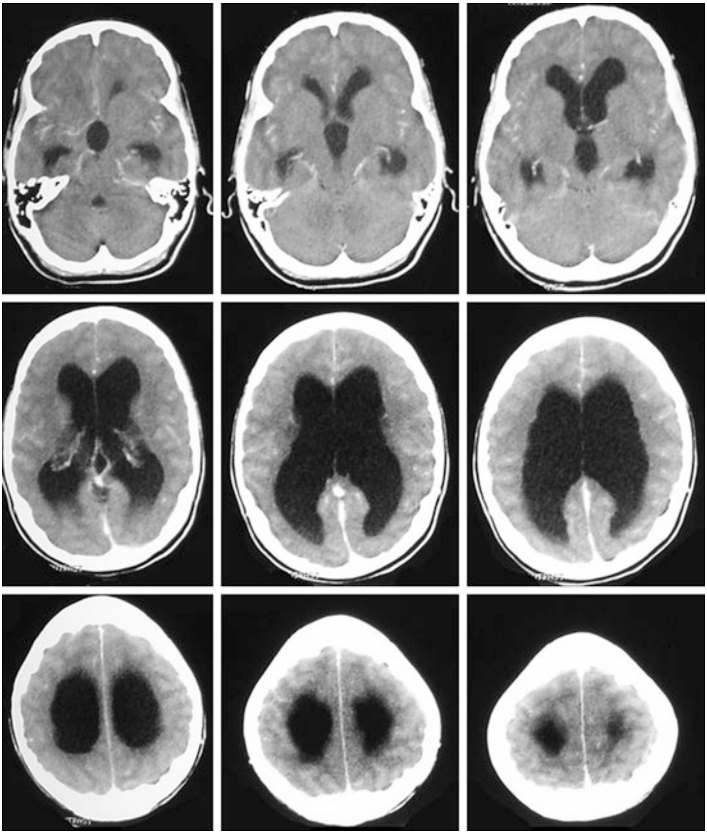

FIGURE 4.8 Non-contrast brain CT scan of a 22 year old male with 3 weeks history of headaches and blurring of vision. Note the gross dilatation of the lateral ventricles (*the frontal horn, the body, occipital horn and temporal horns*) and the third ventricle. The sulci are effaced (see text)

good indication of raised pressure within the ventricular cavity suggesting that the large ventricles are not passive dilatation due to loss of brain tissue (cerebral atrophy) but the result of forced enlargement like as if someone had blown water into a balloon (the brain).

4.4 Disproportionately Small Fourth Ventricle

Also evident in Fig. 4.8 is the fact that the fourth ventricle appears disproportionately smaller in size compared to the size of the lateral and third ventricles. It suggests that the fourth ventricle is not dilated which means the obstruction to CSF flow is before (proximal) to the fourth ventricle. It is an insight that comes readily with seeing many CT scans, so I strongly suggest you pay attention to the size and shape of the fourth as you look at CT scans. We will come back to this in the next session on the causes of hydrocephalus. Figure 4.8 is a case of aqueduct stenosis presenting in later life.

4.5 The Frontal and Occipital Horns

By far the larger and more prominent part of the ventricular system is the body of the lateral ventricle with the associated frontal and occipital horns. It is variable in size and highly susceptible to the effects of cerebral atrophy. For instance, cerebral atrophy leads to ex-vacuo dilatation of the ventricles in both children and adults. Comparison of Figs. 4.7 and 4.8 on the one hand with Figs. 4.9 and 4.10 illustrates the changes in the body of the lateral ventricle in hydrocephalus. Note that Fig. 4.9 represents normal (but significant) variations in the size of the lateral ventricles as in the two children illustrated here.

In hydrocephalus the frontal and occipital horns become rounded in shape and larger than the normal variations illustrated in Figs. 4.9 and 4.10. A case of gross (severe) hydrocephalus is illustrated in Fig. 4.11 which shows the obvious enlargement and the rounded nature of the occipital horn (OH) and frontal horn (FH) in hydrocephalus in addition to illustrating periventricular low density (also called periventricular lucency, PVL).

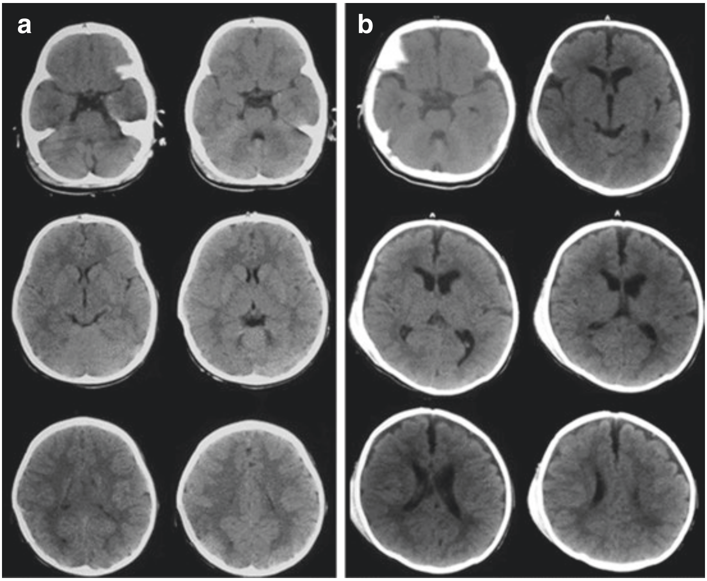

FIGURE 4.9 Non-contrast CT scan showing normal variations in the size of the lateral ventricles of two children (**a**) and (**b**). Note that in spite of the larger lateral ventricles in (**b**), the occipital horns remain narrow and the third ventricle shows no signs of ballooning out and the temporal horns remain small making this a normal variant

4.6 Periventricular Lucencies (PVL)

In Fig. 4.11 the white matter next to the frontal horns appear darker than it is elsewhere, giving the visual image of a teddy-bear with an ill-fitting small cap. That dark cap over the frontal horn is a sign of very late and severe hydrocephalus. There are few exceptions but suffice it to say that it is safe to always treat this as evidence of severe hydrocephalus until proven otherwise. The appropriate action will be to make sure a neurosurgeon evaluate the patient and the scan promptly.

With the above steps you will most likely be able to make a judgment on whether the ventricles are enlarged or not in the majority of cases and we have covered some of the subtle signs of raised intracranial pressure such as periventricular low densities (lucencies) and effacement of the sulci.

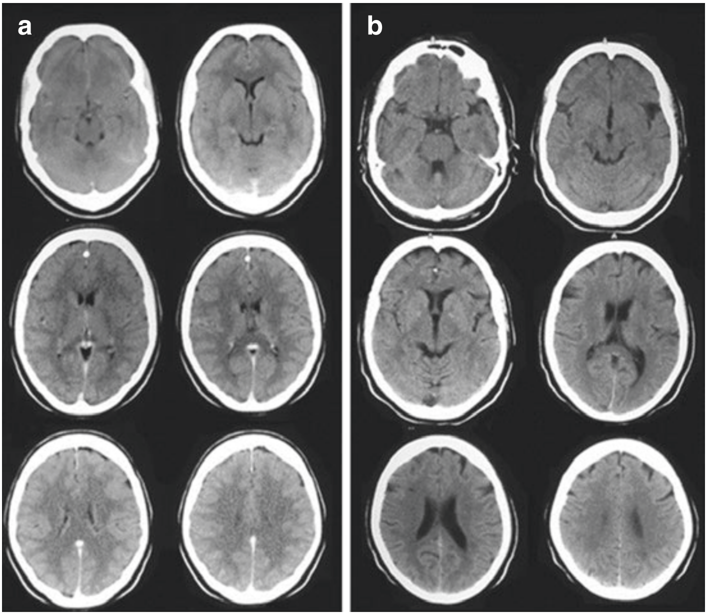

FIGURE 4.10 Non-contrast CT scan showing normal variations in the size of the lateral ventricles of two adults (**a**) and (**b**). Similar to Fig. 4.9b, the adult CT with larger ventricles (**b**) also show narrow occipital and frontal horns along with readily visible sulci making this a normal variant. Compare with Fig. 4.8 in which the frontal horn and occipital horn are rounded in appearance and the sulci are effaced

4.7 Previously Diagnosed Hydrocephalus

The next group of patients are those with a ventriculoperitoneal shunt (or previously treated hydrocephalus e.g. third ventriculostomy or excision of posterior fossa tumor). The systematic approach to looking at the CT scan is exactly the same except that you have the advantage and ***responsibility*** to obtain the previous imaging and compare with the present CT scan to see if the ventricles are bigger (Fig. 4.12a, b). It helps to focus on the same areas such as the temporal horns and the third ventricle and then the lateral ventricles; comparing the new CT scan with the very last scan ***when the***

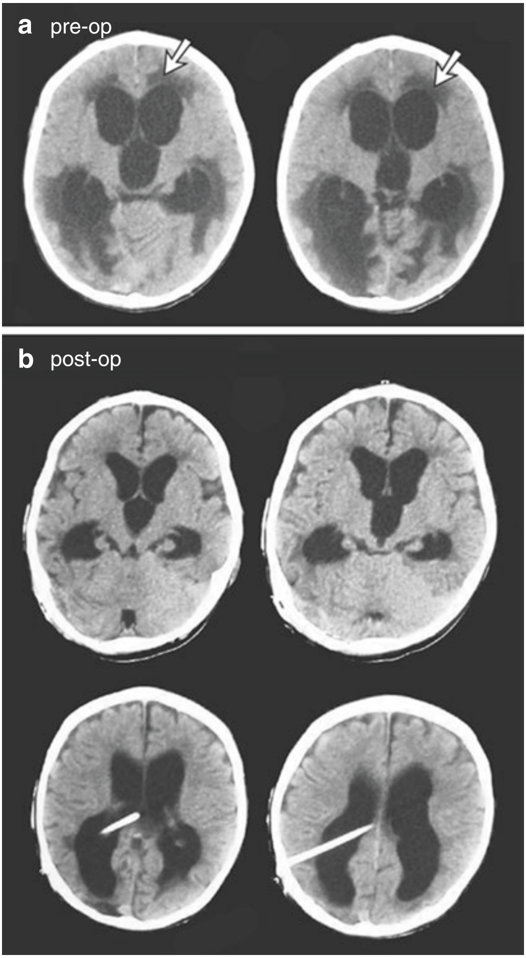

FIGURE 4.11 (**a**) Non-contrast brain CT scan showing severe hydrocephalus characterized by the ballooned (Mickey mouse shaped) ventricles with periventricular lucencies (white arrows). Note also the effacement of the sulci due to the grossly dilated ventricles. (**b**) The same patient following a successful ventriculoperitoneal shunt. The periventricular lucencies have disappeared and the sulci are clearly visible under the skull. The ***ventricles*** are smaller than in (**a**) and not under pressure anymore. And this is the new normal appearance for this patient even though the ventricles remain relatively big. The ventricles don't always shrink to the size seen in Fig. 4.10a or b

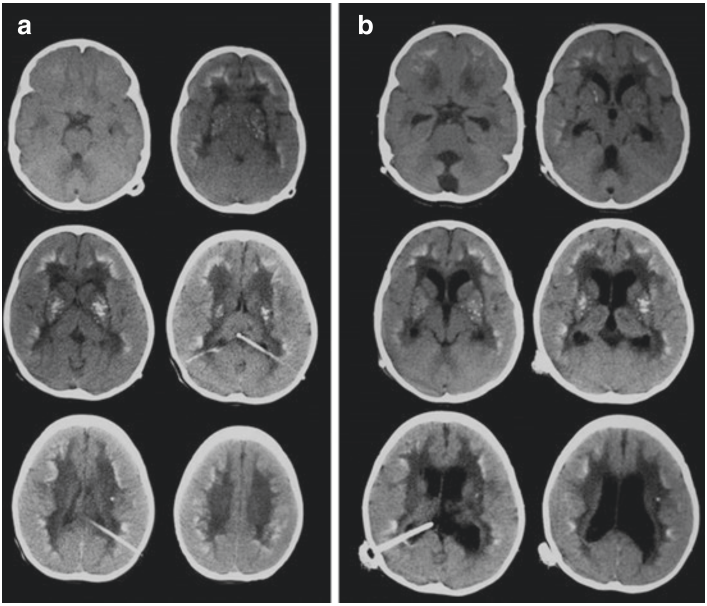

FIGURE 4.12 Non-contrast brain CT scan showing two scans (**a** and **b**) from a patient with a ventriculoperitoneal shunt. It is important to note that there is pan ventricular dilatation in (**b**) with obvious dilatation of the temporal horns and third ventricle due to shunt malfunction. In less obvious cases a detailed comparison of the previous scan (**a**) with the new scan (**b**) is essential

patient was well. Although comparison with previous imaging makes any changes in ventricular size obvious, it is important to realize that if such imaging is not available then the same principles outlined above should be used to evaluate the brain CT scan you do have.

4.8 Causes of Hydrocephalus

Although it is true that hydrocephalus is always secondary to some underlying pathology or anomaly, from a practical point of view it is important to determine if there is only a CSF flow obstruction as in aqueduct stenosis or there is another serious

underlying pathology like a tumor or a clot that may require treatment in its own right. Thus, the final question you ask yourself after you see evidence of hydrocephalus on the CT scan is this: *what is the cause of the hydrocephalus?* Figure 4.8 is an example of aqueduct stenosis such that relieving the CSF obstruction results in cure. On the other hand, the enhancing (white) cerebellar tumor in Fig. 4.6c above is the primary diagnosis and the hydrocephalus is the secondary effect, a concept worth keeping in mind as you study the following cases in which the hydrocephalus is only part of the diagnosis and the underlying cause should be emphasized.

It is beyond the scope of this book to detail all the possible causes of hydrocephalus from the choroid plexus to the dural venous sinuses, therefore only striking illustrations will be given but the concept ought to be clear that hydrocephalus can occur from either CSF over production (choroids plexus papilloma) or reduced absorption. The reduced absorption can either be from obstruction or other mechanisms. By and large the majority of cases are from obstruction which is secondary to either a congenital lesion, tumor, hemorrhage or infection. Fortunately, these are easy to differentiate from the history and physical examination and a review of the brain CT scan.

4.9 Foramen of Munro: Colloid Cyst

A colloid cyst is a classic example at this location and is illustrated in Fig. 4.13.

4.9.1 Obstruction of the Cerebral Aqueduct of Sylvius by Tumor

In the post contrast CT scans Fig. 4.14c and the sagittal MRI (Fig. 4.14b), you can make out the enhancing pineal tumor. The most important lesson from these series of images is that in aqueduct stenosis the third ventricle is enlarged whereas when the obstruction is before the third ventricle as in the foramen of Munro, the third ventricle is collapsed.

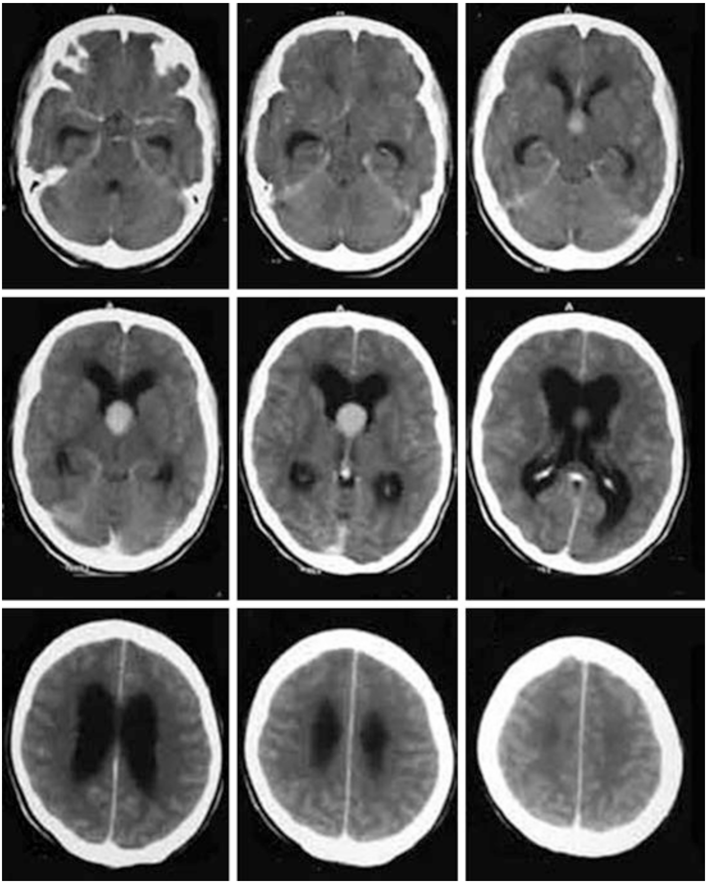

FIGURE 4.13 Post-contrast axial CT scan showing an anterior third ventricle colloid cyst blocking both foramina of Munro and causing severe hydrocephalus. Note that the third and fourth ventricles are small or normal because the obstruction is proximal to this level

4.10 Dandy Walker Malformation

Most of the causes illustrated so far are acquired. Although not very common, Dandy Walker malformation describes congenital absence of the lower back side of the cerebellum (inferior cerebellar vermis) so that you see the gutter-like

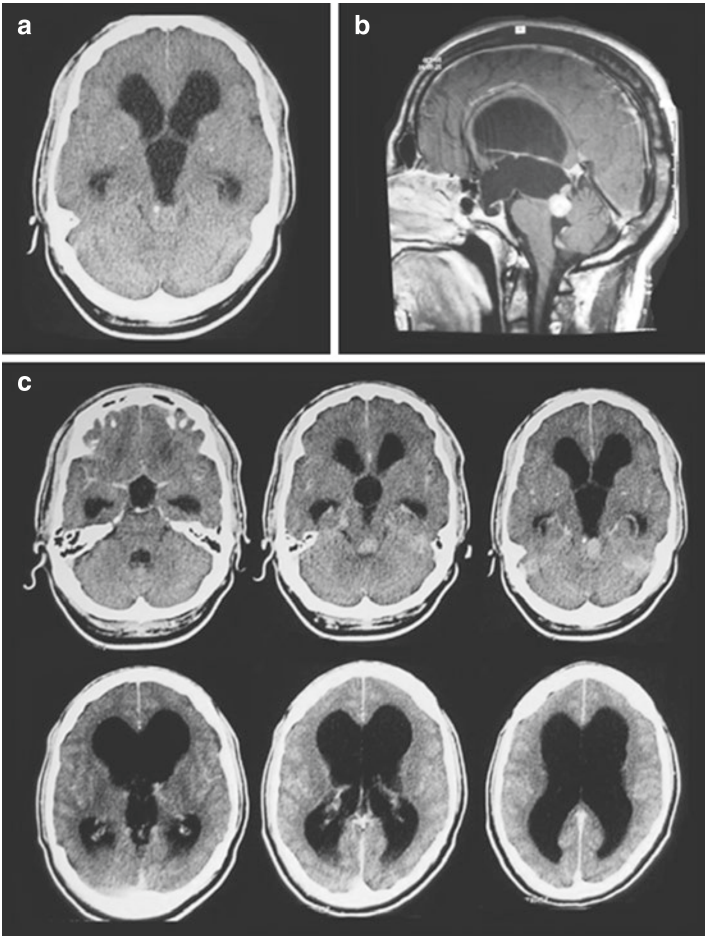

FIGURE 4.14 Aqueduct obstruction from pineocytoma. (**a**) Non-contrast axial CT; (**b**) sagittal post contrast MRI showing the enhancing nodule of tumor causing the obstruction; (**c**) post contrast CT scan showing the enhancing nodule as seen on CT. Note that the third ventricle is larger than the fourth, a reversal of the normal situation which is the hallmark of aqueduct stenosis (compare Fig. 4.10b) no matter the cause

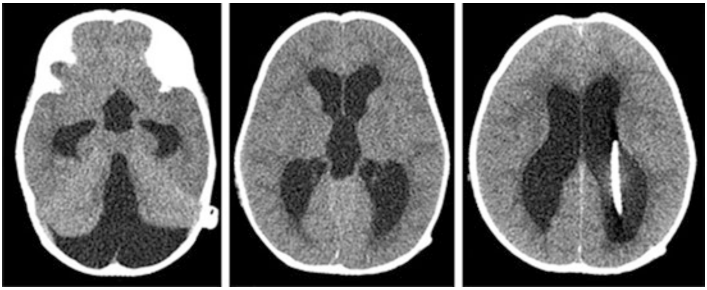

FIGURE 4.15 A patient with Dandy Walker malformation and hydrocephalus who has a left ventriculoperitoneal shunt in place

appearance in Fig. 4.15 and the fourth ventricle is widely open to the large CSF space between cerebellum and medulla. Although there are several hypothesis for the development of hydrocephalus it is unclear beyond the fact that some of the patients also have aqueduct stenosis.

Chapter 5
Tumours and Infections (☞ SOL)

5.1 Introduction

Brain tumors and abscesses (which most physicians refer to collectively as space occupying lesions—SOL) exert a significant mass effect on the brain. In addition, most radiologists would recall trying to differentiate a tumor from an abscess and vice versa. The distinction is ***critical*** for obvious reasons—a brain tumor like a glioblastoma is effectively a terminal illness whereas most bacterial abscesses are curable with antibiotics and drainage. It is to emphasize this distinction and the urgency to come to a conclusion in both cases that we are discussing these two subjects in the same chapter. By and large both lesions will present with one or more of the following clinical problems: features of raised ICP, convulsions, headache, focal neurological deficit (like hemiparesis or speech disturbance) plus or minus altered level of consciousness. Fever is variable even in brain abscesses. Slow growing tumors may give rise to a longer duration of symptoms.

In the preceding chapters we have simply discussed obvious lesions with little need for differential diagnosis. Tumors such as meningiomas (Fig. 5.1) are again obvious and call for little differential diagnosis. However, the majority of metastatic tumors and intrinsic high-grade gliomas which together makeup the majority of tumors seen in emergency

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In Clinical Practice, https://doi.org/10.1007/978-3-030-14828-7_5

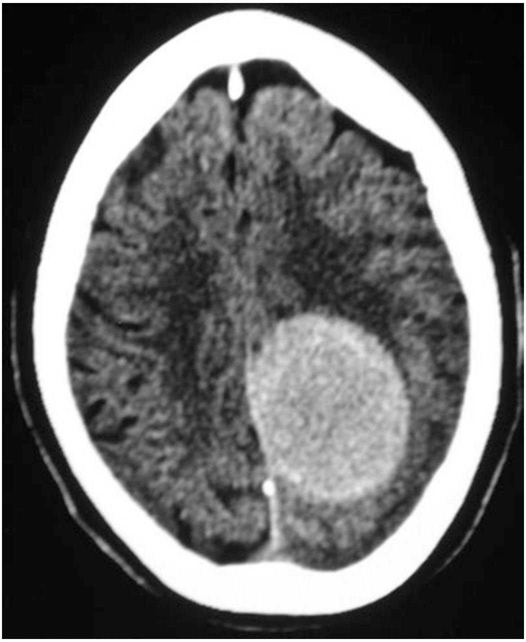

FIGURE 5.1 Contrast-enhanced brain CT scan illustrating a uniformly enhancing left parafalcine meningioma. Note that it is solid and very ***unlike*** an abscess. It is benign and carries a good prognosis

medicine may need to be distinguished from an abscess. We will try and simplify this process so that you can deal with the 80% or more of the straightforward cases without feeling turned into a neuroradiologist! Let us look at the basics of describing any tumor or abscess which I have reduced to the acronym MEAL. (Well, we will try not to *make a meal of it*!)

5.2 M Is for Mass Effect

The concept of mass effect was introduced in Chap. 1. Comparing the appearance of the sulci and gyri between the two sides (right and left) of the brain makes any differences

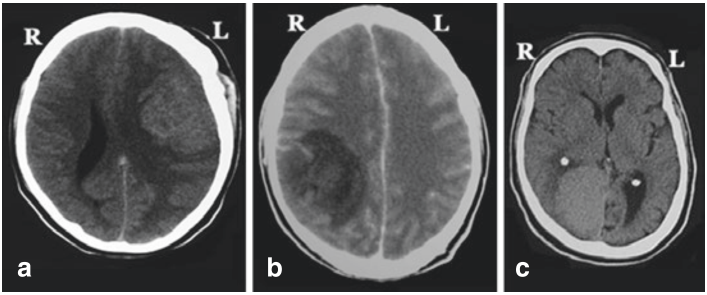

FIGURE 5.2 Non-contrast brain CT scan showing alterations of the normal sulcal pattern as evidence of mass effect from an isodense meningioma (**a**), a low-density glioma (**b**) and a slightly hyperdense meningioma (**c**)

apparent. (If you have any doubt about the appearance of gyri and sulci on the CT scan, then this is a good time to revise Chap. 1 especially Figs. 1.10, 1.11 and 1.15.) The side with a tumor or abscess is more likely to have the sulci squeezed (effaced) and often the lateral ventricle on that side is also compressed (Fig. 5.2c). In more severe cases, there is midline shift towards the normal side. This is often the first clue that there may be a lesion (Fig. 5.2a), prompting the intravenous injection of contrast (see below) to see if the lesion takes up contrast and become brighter. Review the examples in Fig. 5.2 and see if you can describe the abnormality in the CT scan in each case (a–c).

Most brain tumors will declare their presence by a significant mass effect from their share ***size*** (Fig. 5.2a, c) or by the ***severe edema*** around them (Fig. 5.3).

However, some other lesions show very little mass effect and are only identified on close systematic scrutiny of all the images. For example, in Fig. 5.4a, the tumor shows little or no mass effect.

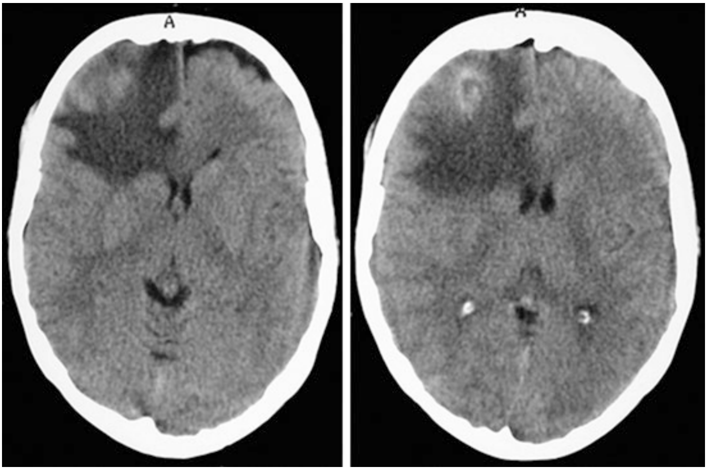

FIGURE 5.3 Non-contrast brain CT scan showing severe right frontal edema with mass effect. The right frontal horn is effaced (not seen) whereas the left is clearly seen. The sulci and CSF subarachnoid spaces are more easily seen on the left than on the right and there is midline shift to the left seen more clearly in the image on the right

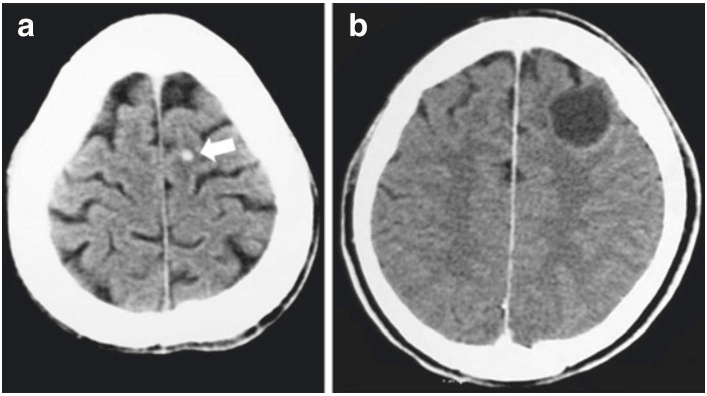

FIGURE 5.4 (**a**, **b**) Are different patients with axial CT scans illustrating a small hyperdense lesion with no mass effect (**a**) and a larger left frontal low-grade glioma with slight mass effect. Note that the sulci are clearly visible and almost undisturbed by the left frontal lesion (see white arrow, **a**)

5.3 E Is for Enhancement

"Enhancement simply means it is appearing clearer" and in this case higher density (brighter) compared to the pre-contrast CT scan. Certain CT contrast agents like iohexol (non-ionic) appear hyperdense on CT scan. When injected intravenously they concentrate in vascular areas of the brain including tumors and abscess walls thereby making them appear hyperdense and hence easier to see (for instance enhancing their appearance). The neovascular capillaries of tumors and the abscess wall are often porous allowing some of the contrast to leak into the interstitial area thereby accumulating in the tumor or abscess wall ***for sufficiently long enough time to be imaged.***

Meningiomas and lymphomas tend to enhance uniformly and intensely whereas malignant gliomas and abscesses may show an intermediate degree of enhancement in which there is an outer enhancing ring surrounding a core of non-enhancing low density (necrotic centre) which fails to take up the contrast (Figs. 5.5 and 5.7). Abscesses (Fig. 5.6) typically show a ***uniform, thin*** enhancing wall surrounding the pus whereas the ring of enhancement in gliomas is thicker with more solid tumor in the wall (Fig. 5.7).

In general abscesses have a thinner and smoother enhancing ring with no chunk of enhancing tumor along the wall. Whereas the enhancing ring in malignant gliomas and metastatic tumors tend to be thicker and irregular and there may be an asymmetric large chunk of enhancing tumor as part of the wall (Fig. 5.7). By these descriptions Fig. 5.8a should be an abscess and Fig. 5.8b a tumor but the ***reverse*** is true. Figure 5.8b was actually biopsied and confirmed to be a tuberculosis granuloma which disappeared completely with antituberculous treatment and Fig. 5.8a was confirmed a metastatic tumor from the lung. Unfortunately, such ***exceptions*** to the general description given here are common, because the similarity between brain abscesses and malignant tumors is not only in appearance but the result of their common biological aggressiveness in destroying everything in

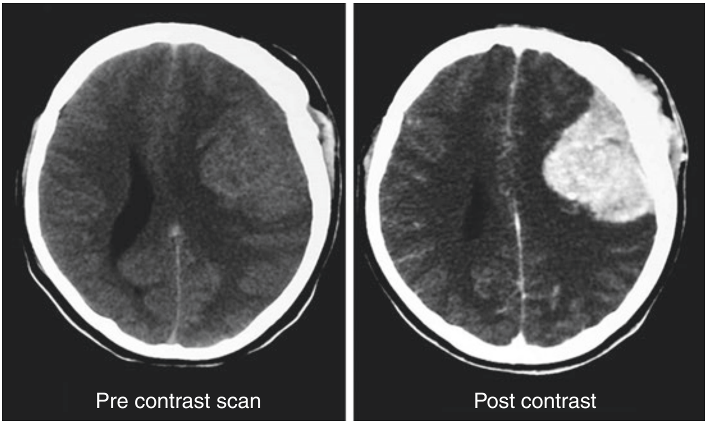

FIGURE 5.5 Shows the pre and post contrast CT scans of a 22-year-old male that presented with his first grand mal fit. He admitted to having a large mass on the left side of this head for over 1 year. This history clearly suggests a slow growing tumor like a meningioma. Identification of a mass lesion is so much easier if there is significant enhancement. The pre-contrast scan is same as in Fig. 5.2a. The effect of the contrast enhancement is obvious. Although the meningioma is isodense and can only be inferred from the mass effect (effacement of the sulci, compression of the left lateral ventricle and midline shift), the contrast enhancement makes it obvious

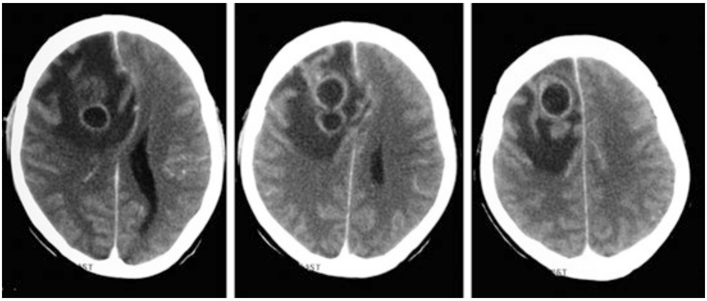

FIGURE 5.6 Contrast enhanced brain CT scan showing a brain abscess in a 38-year-old man on immunosuppression therapy for SLE. Not the smooth outline of the rings of enhancement

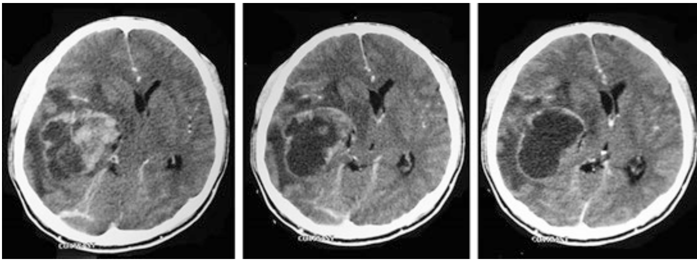

FIGURE 5.7 Contrast enhanced brain CT scan showing right temporal gliobastoma in a 21-year-old male with first grand mal seizure. Note the solid mass of enhancing tissue, the cystic non-enhancing core and the severe mass effect with effacement of the right lateral ventricle and midline shift. This requires urgent neurosurgical referral due to significant midline shift and brain compression

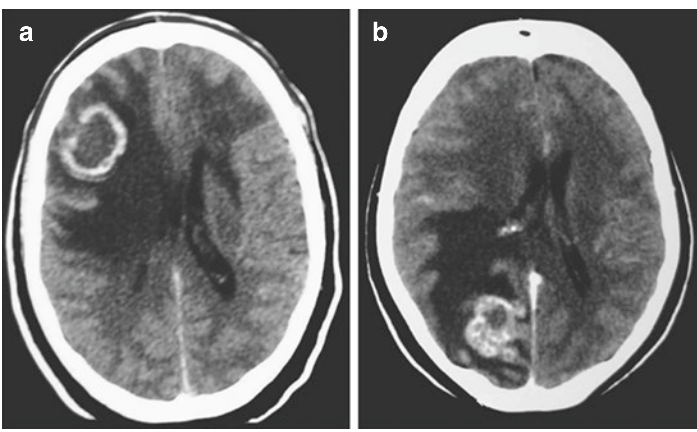

FIGURE 5.8 (**a**, **b**) Are post-contrast CT scans showing two obvious lesions. This picture is intended to reinforce the not infrequent similarity between tumors and infective lesions. Image A is a metastatic lung carcinoma and image B is a biopsy proven tuberculosis (TB) granuloma

their path as they advance into the surrounding brain like an "*invading army*'. The result is often the same—*death and destruction*; no matter the 'regiment[1]' carrying it out! Thus,

[1] Cancer or bacteria.

malignant gliomas and abscesses both leave necrotic tissue on their imperial path hence the similar appearance. ***Therefore, it has to be emphasized that for the frontline doctor, an accurate description of the lesion is far better than an attempt at histological exactitude from the CT scan.***

You should note carefully that tumors like meningioma do not look like abscesses and are therefore not easily confused.

Malignant gliomas and metastatic tumors ***share*** the property of ring enhancement with abscesses and are therefore the subject of much clinical controversy. ***From a frontline physician's point of view, describing accurately what the lesion looks like on the emergency contrast enhanced CT scan to a neurosurgeon is more than adequate and it will be the responsibility of the neurosurgeon and neuroradiologist to consider the differential diagnosis.*** For the anxious patient and relative, the frontline doctor simply has to be honest and say that the exact nature of the mass lesion can only be confirmed after a biopsy and guessing is unwise—which is true as exceptions are common (Fig. 5.8). However, it is imperative for the physician to be able to say if there is significant mass effect or immediate risk to life based on the presence or absence of the specific features discussed in the section on ***red flags***.

Enhancement is a common feature of infective lesions. Most brain abscesses (pyogenic and granulomatous) will show ring enhancement when a mature abscess exists. The difference between a subdural hematoma and empyema (Fig. 5.9) may well depend on the presence or absence of a how vivid the enhancement is, if the clinical features are equivocal. And in meningitis the meninges show widespread enhancement. Thus, the presence or absence of enhancement should be evaluated carefully. Having raised your awareness to think of metastasis, glioma and abscess when you have a ring-enhancing tumor, it is important to point out that both metastasis and gliomas could appear as solid tumors prior to the formation of a necrotic centre. ***Again, the emphasis should be to determine if there is any mass effect and if the lesion poses immediate risk to life (see red flags below) rather than the accuracy of the differential diagnosis.***

FIGURE 5.9 Contrast-enhanced brain CT scan showing the enhancing rim surrounding a subdural empyema

5.4 A Is for Appearance

Appearance simply means 'what does it look like'? What is the shape of the mass or tumor you have seen. Usually the pre and post contrast films should be examined and as much as possible avoid trying to describe a scan from memory. Always have the films or images in front of you, when you are trying to describe it to someone on the phone or write down a comment in the patient's file. The first thing you notice about the appearance of any lesion is whether it is hyperdense, isodense or hypodense on the pre-contrast images. Note that hyperdense lesions imply blood or calcification. Hypodense lesions usually signify oedema or fluid. The post contrast film is then scrutinized to determine the shape of the enhancing component. ***A uniform enhancement***

implies a solid mass like a meningioma (Figs. 5.1 and 5.5)***; a patchy irregular enhancement will suggest a partially solid and cystic tumor like a glioma*** (Fig. 5.10) ***and a ring enhancing, circular lesion*** (Fig. 5.11), ***will suggest an abscess with the important differential diagnosis of a metastasis or glioma.***

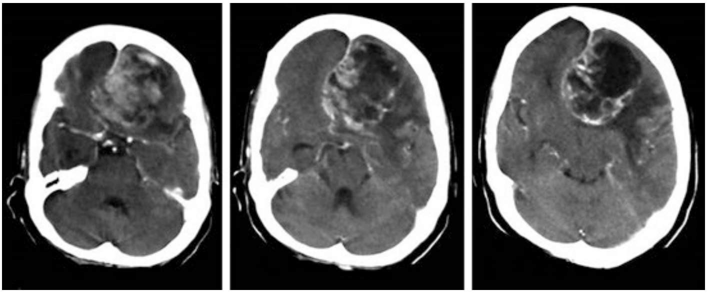

FIGURE 5.10 Contrast CT scan showing a left frontal irregularly enhancing tumor with solid and cystic components. This is a the typical appearance for a high grade glioma usually glioblastoma

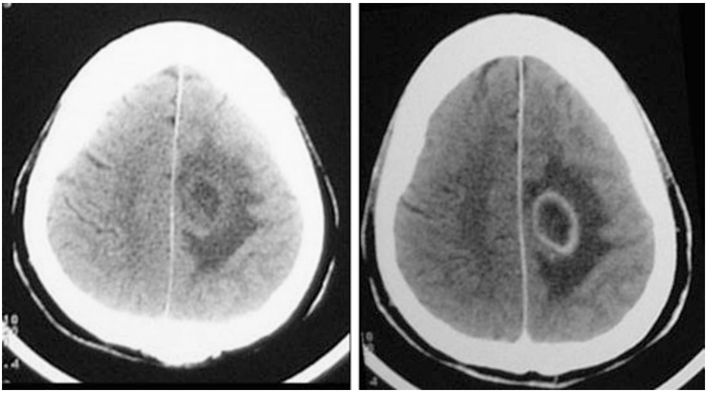

FIGURE 5.11 Pre and post contrast CT scan showing a left parietal ring enhancing lesion with surrounding edema (low density area). Stereotactic aspiration showed a Nocardia brain abscess

5.5 L Is for Location

Sixty percent of primary tumors in adults are supratentorial and 40% occur in the posterior fossa. However, the reverse is true for children with 60% of childhood brain tumors occurring in the posterior fossa and 40% in the supratentorial area. One of the critical factors about the location of a tumor is the propensity for complications. Colloid cysts in the third ventricle typically cause hydrocephalus (Fig. 4.12) and may result in sudden death from unrecognized and acutely progressively raised ICP. A tumor in the temporal lobe frequently presents with epilepsy and easily compresses the brain stem. Posterior fossa tumors often cause hydrocephalus (Fig. 4.5c). Therefore, the location is important and is one vital piece of information the neurosurgeon may want to know on of the phone. It is perhaps superfluous at this stage to emphasize that it is imperative to note whether the lesion is in the left or right hemisphere and which part of the brain—frontal, parietal, temporal or cerebellum or brain stem. Brain stem lesions are often difficult to see unless the clinical history leads you to search carefully (Fig. 5.12).

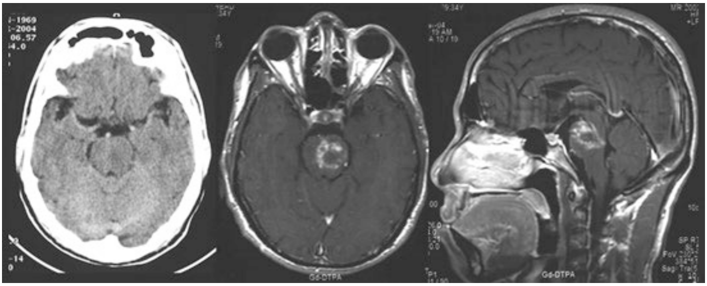

FIGURE 5.12 The CT scan on the left hardly gives any clue of the fatal brain stem glioma easily displayed by the MRI. ***If the patient has obvious clinical signs and symptoms, then you must scrutinize the image for the hidden clue which here is the enlarged pons and central low density. Remember to have a contrast enhanced image!***

Brain tumors broadly occur in ***two layers***: those tumors arising from and located in the coverings of the brain including the skull base (meningiomas) versus those that are located within the substance of the brain itself (gliomas and metastasis). Although there are many exceptions such that large gliomas may come to the surface touching the skull (Fig. 5.13), meningiomas however arise from the meninges and therefore tend to make broad contact with the dura (along the vault, the sphenoid wings and the falx cerebri) often displaying an enhancing tail that is typical of these tumors (Fig. 5.14). On the other hand, gliomas and metastasis generally have the epicenter of the tumor located in the white matter (Fig. 5.13) even if it extends to the surface. This basic fact from the CT scan, applied correctly with other factors such as the appearance and enhancing characteristics will allow identification of the common tumor types even by a frontline doctor.

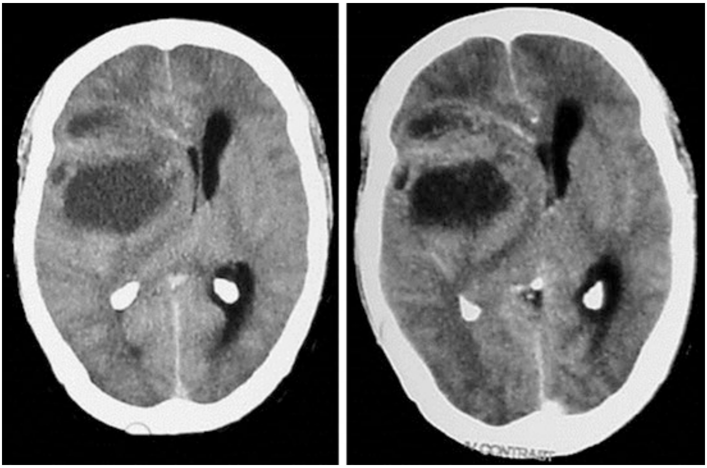

FIGURE 5.13 Contrast-enhanced CT brain scan showing a moderately enhancing right frontoparietal glioma coming to the surface. Note it is multicystic with a significant mass effect. The right frontal horn is completely squashed and there is midline shift to the left

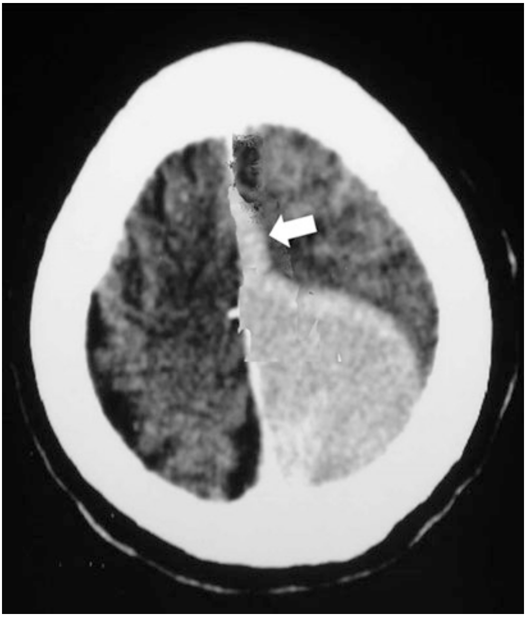

FIGURE 5.14 Contrast-enhanced CT brain scan showing a typical meningioma arising from the falx cerebri and manifesting an enhancing dural tail (the white arrow)

Thus, if you describe a uniformly enhancing tumor with a broad-based attachment to the dura, it is a meningioma until proven otherwise. If you describe a ring-enhancing lesion located deep in the white matter, you most likely have a glioblastoma or an abscess or a metastasis (Fig. 5.15).

5.6 Special Locations

Tumors of the pituitary fossa and cerebellopontine angle often come with a suggestive history of visual failure and deafness respectively, which requires these areas to be scrutinized carefully. It is self evident how easy it is for a beginner to miss the pituitary tumor illustrated in Fig. 5.16. Furthermore,

Figure 5.15 Contrast-enhanced brain CT scan showing a typical left frontal glioblastoma multiformi, which is centered in the white mater with surrounding edema coming to the surface

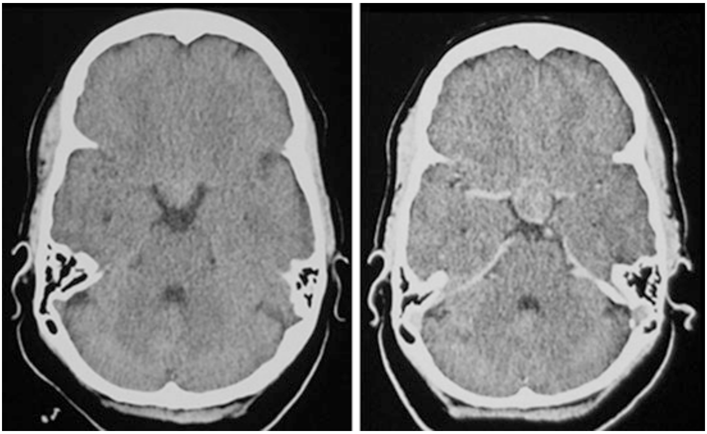

Figure 5.16 Pre and post contrast Brain CT scans showing a pituitary adenoma

small tumors in the posterior fossa maybe missed either due to artifacts from the surrounding bones or lack of systematic evaluation of the posterior fossa in the CT scan (Fig. 5.12).

Although certain tumors occur in certain locations and childhood tumors tend to differ from adult tumors, it is more important to describe accurately the lesion seen on the pre and post contrast CT scans rather than a pedantic assertion of tumor type, because CT radiological assessment of histological types or grade is at best imprecise. Therefore, the above summary is intended to give you the tools with which to describe a tumor or any mass lesion accurately.

Red Flags

1. ***Large size tumor or abscess.***
2. ***Significant midline shift over 5 mm.***
3. ***Contralateral hydrocephalus***
4. ***Brain stem compression***
5. ***Altered level of consciousness***
6. ***Fixed and or dilated pupil.***

Chapter 6
Advanced Uses of Brain CT Scan

6.1 When Chaos Becomes a Concept

The image in Fig. 6.1 contains a lot of information which to the untrained eyes will be chaotic, confusing and complicated. However, by following the basic principles we learnt and without being distracted by the metal artefact from the cochlear implant you can describe what is important to the neurosurgeon, in fact that this patient is herniating and requires immediate neurosurgical intervention.

Exercise 6

Can you list three abnormalities with the non-contrast CT scan in Fig. 6.1. Suggested answers are listed at the end of this chapter.

In comparing Figs. 6.1 and 6.2, you will appreciate that despite the artefact from the cochlear implant, you can make out that there is no large blood clot inside the head in Fig. 6.2. Moreover, the CSF spaces on the right side are visible and there is no midline shift in Fig. 6.2. And the symmetry of the CSF spaces within the brain itself is maintained. Therefore, you can conclude that in Fig. 6.2, there is no obvious abnormality other than the artefact from the cochlear implant. In other words, if you stick to the basic principles we have learnt such as comparing the CSF spaces between left and right, and

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In Clinical Practice, https://doi.org/10.1007/978-3-030-14828-7_6

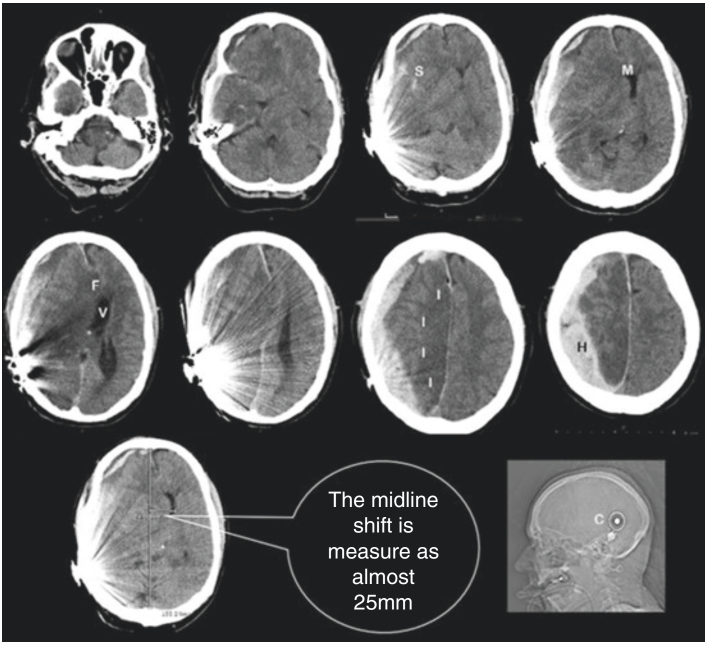


FIGURE 6.1 Non-contrast scan of a 62-year-old male following a motor vehicle collision. The patient was GCS 7 with fixed and dilated right pupil. See answer to Exercise 6 for description of findings

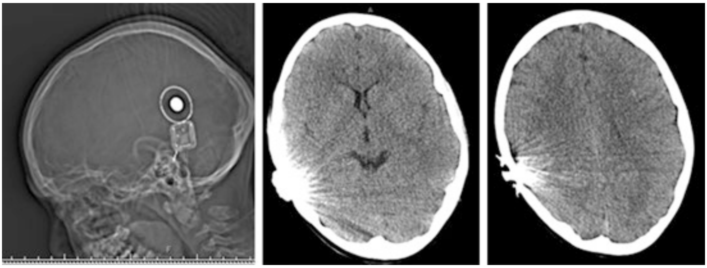


FIGURE 6.2 Is a non-contrast CT brain scan from of another patient with a cochlear implant showing no focal abnormality

the integrity of the midline of the brain, it is likely to lead you to the correct conclusion.

6.2 The Importance of Basic Anatomy

The only reason an assailant such as an armed robber points the gun at your head is because he or she knows that the brain is inside there. So even the armed robber needs and uses some basic anatomy with deadly effect! The importance of some basic anatomic information to interpreting a brain CT scan cannot be overemphasized. One good illustration of this principle is the cerebral venous sinuses. They are intimately related to the skull, therefore if you have a skull fracture or gunshot wound going through the area of a vascular sinus, you need to think immediately about whether the sinus is affected or not. One good way of doing this is CT venography and CT angiogram. Figure 6.3 is non-contrast CT scan with 3D rendition of the skull as well as axial cut showing a depressed skull fracture directly over the transverse sinus and torcula heterophili.

If you see a CT scan like that, not only is the depressed fracture obvious, you automatically want to get a CT veno-

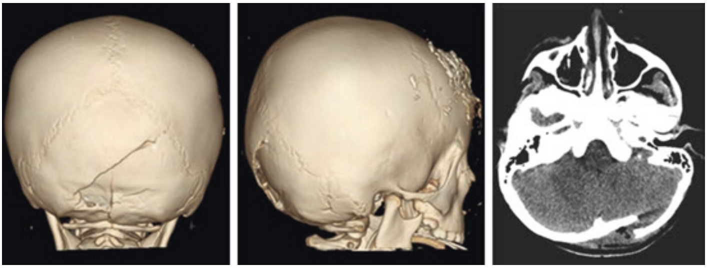


FIGURE 6.3 Non-contrast CT head of a 5-year-old boy who was accidentally run over by a car. There is a depressed fracture in the posterior fossa with no significant hematoma. The rest of his CT head showed no other lesions or swelling. The integrity of the underlying sinus needs to be investigated promptly

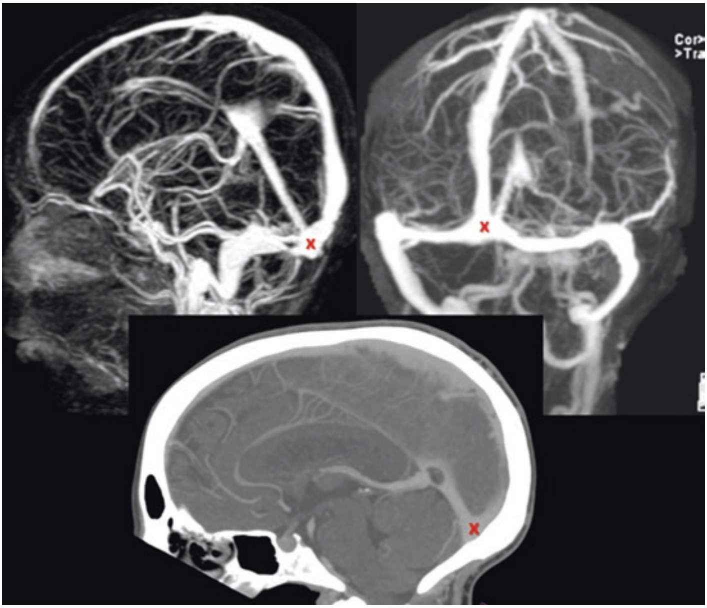


FIGURE 6.4 Venogram showing the close relationship of the sinuses to the skull, hence a skull fracture can easily compress or tear the sinus. The confluence of sinuses called the torcula heterophili is marked with a red **X**

gram or MR venogram to investigate the venous sinuses. The assignment therefore, is for you to familiarize yourself with the locations of at least the major sinuses; of which three are likely to be encountered most frequently: the sagittal and the two transverse sinuses (Fig. 6.4). The transverse sinus on each side continues as the sigmoid sinus which becomes the internal jugular vein in the neck.

6.3 3D Renditions: Head and Neck

Three-dimensional rendition (Figs. 6.3 and 6.5) of the CT images gives incredibly beautiful and confirmatory pictures of the skull bones in trauma and in cases of craniosynostosis

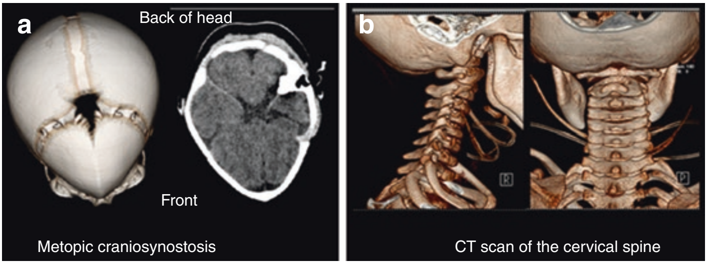


FIGURE 6.5 3D CT scan of the skull showing fused metopic suture (**a**). (**b**) Shows a 3D CT scan of the neck. Note that a neck CT is often obtained along with the head in severe trauma: remember ABC and "s". The 'S' is for the cervical spine!

in children. In Fig. 6.5a, the two frontal bones are fused prematurely resulting in the forehead being narrowed into a triangular peak (trigonocephaly) like the keel of a boat. Figure 6.5b illustrates the 3D rendition of a cervical CT spine. This picture reminds me to mention that a neck CT scan is often obtained at the time of a head CT in severe trauma. The clarity of the 3D images is obvious. Special uses like these are only limited by the dose of radiation necessary to obtain this quality of pictures.

6.4 3D Renditions: CT Angiography

Although digital subtraction angiography remains the gold standard for investigating the brain vessels especially for aneurysms, increasingly sophisticated CT imaging protocols allow the visualization of the cerebral vessels (CT angiography Fig. 6.6) in three-dimensions, providing useful information and in some centers obviating the need for standard angiography in medical decision making.

The veins are also evaluated (CT venography) similarly and an enhanced example is shown in Fig. 6.7, underscoring the important point that the main veins (sinuses as they are called in the head) hug the skull closely making

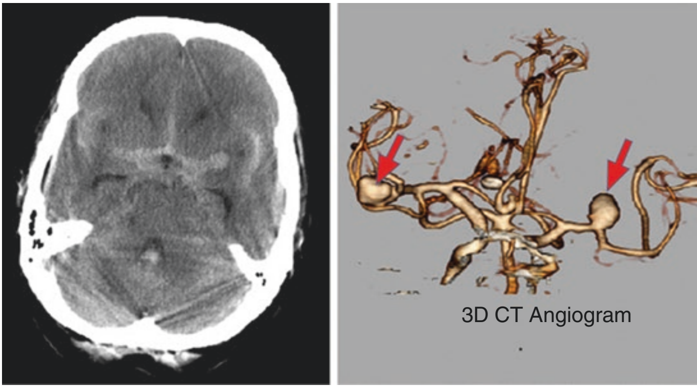


FIGURE 6.6 Non-contrast CT scan showing subarachnoid hemorrhage and a 3D CT angiogram showing multiple aneurysms (Left and right middle cerebral artery aneurysms {red arrows}—round blebs on the arterial tree like pumpkins and an ACOM aneurysm {not arrowed})

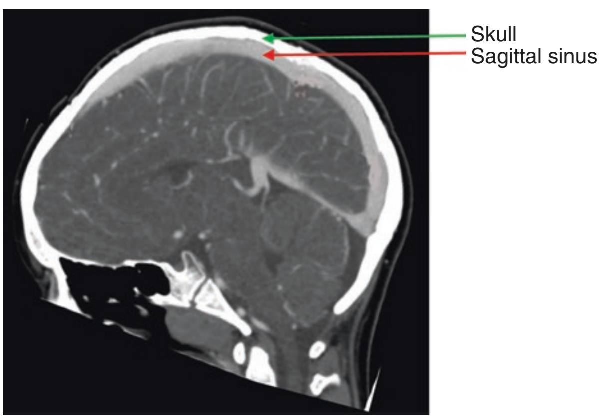


FIGURE 6.7 Pictorially enhanced example of CT venogram showing how the sagittal sinus hugs the skull throughout its course. Well I will tell you this one story alone. I once had a 14-year-old boy whose father took away his play station so that he could study. In protest he took an electric drill and started drilling into the middle of his head. He was less than a millimeter from the sagittal sinus before he was stopped and brought to the hospital. He was perhaps less than a millimeter from death because of these big blood vessels. Therefore, when you see a gun shot wound or fracture near these vessels, beware and treat them with the urgency they deserve

them vulnerable to injury from a skull fracture (Fig. 6.3). *It also emphasizes the need to look carefully because the brightness of the skull tends to overshadow and blur the underlying grey density of the venous sinuses. Changing the brightness of the whole image (the window level) makes it easier to see the veins.*

6.5 CT Perfusion Studies

A CT perfusion study shows the relative distribution of blood flow into different parts of the brain and presents this information in a color-coded fashion that makes the ischemic (stroke) area obvious (Fig. 6.8). It is used in stroke medicine to define the penumbra, which represents brain that is likely to recover if blood flow is restored quickly enough. Figure 6.8 is fascinating in a sense because you have the non-contrast CT scan showing the area of stroke as a low density. Then the CT angiogram shows that the middle cerebral artery on the right side is blocked (absent, not visualized. COMPARE

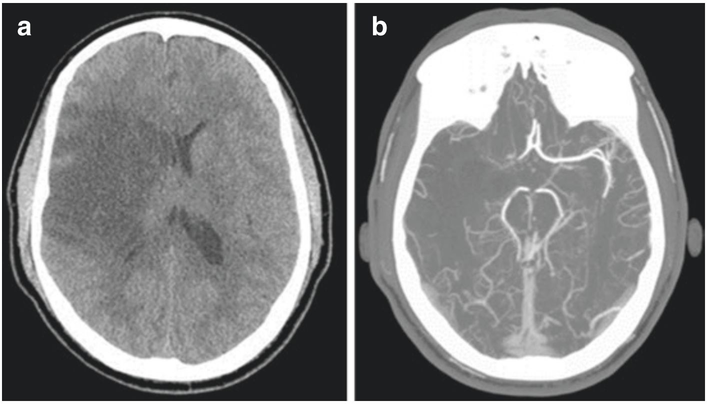


Figure 6.8 Non-contrast CT scan showing low density consistent with right middle cerebral artery infarct (**a**). Concurrently obtained CT angiogram showing occlusion of the right middle cerebral artery (**b**). And the CT perfusion studies highlighting the area of ischemia (**c**, **d**)

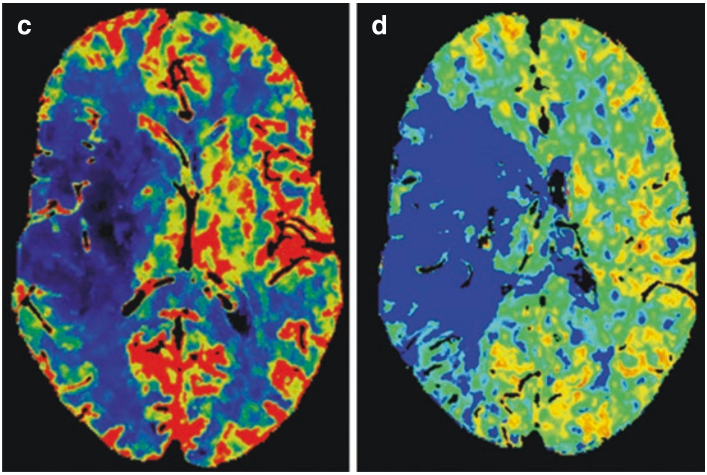


FIGURE 6.8 (continued)

WITH LEFT SIDE). And the perfusion scans show the ischemic area. The detailed interpretation of CT perfusion is beyond the scope of this book but it is illustrated here to show what is possible and for the curious reader to explore further.

6.6 Pitfalls and Subtleties

The most important message in this section is to recognize the limits of your own skill or ability. That is only fair to say because there will always be a CT scan that challenges even the expert and you never know when one such scan will come calling. Therefore, confirming your assessment of the CT scan with the radiologists' report is good practice and a great opportunity to learn. Use the principles you have learnt here but don't hesitate to ask for help because unusual cases such as (Fig. 6.9) are not rare.

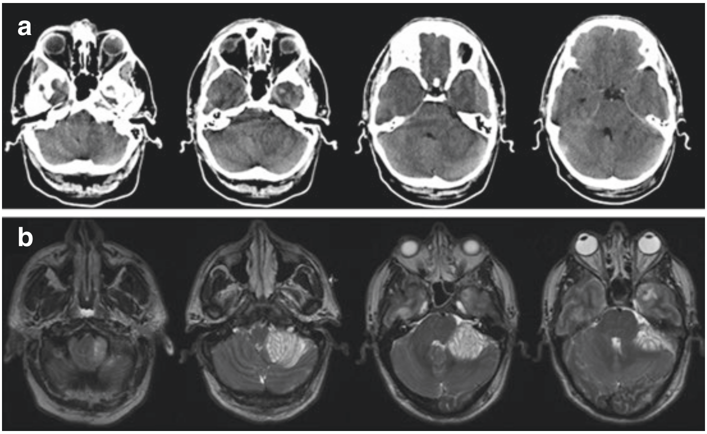


FIGURE 6.9 A 39-year-old male with no previous illness fell off a roof while working on cables. He took to bed to get better but had persistent headaches and vomiting so he reported to the Emergency room of his local hospital. The non-contrast CT scan (**a**) was obtained. In the setting of trauma, the left cerebellopontine angle mass could easily have been overlooked by a beginner, but it is obvious on the MRI scan. It is important to pay attention to the posterior fossa in all scans because of the ease with a lesion can be missed. The tumor (Lhermitte-Duclos disease—dysplastic gangliocytoma) is obvious on the subsequent MRI

6.7 How Does the CT Machine Work?

A brain CT scan machine is shown in Fig. 6.10. The most interesting path is the donut shaped hole which is surrounded by a console. The console contains a rotating X-ray tube coupled to a detector placed 180° opposite the X-ray tube. The patient is introduced into the plane of the rotating X-ray tube and detector system slice by slice.

Hence the slices are produced by moving the patient incrementally through the field. For each slice, the X-ray tube rotates 360° round the patient's head and registers that image. Then the next slice and so on. Sophisticated computing is used to reassemble the slices to form a 3D image as shown in

FIGURE 6.10 A picture of a CT scan machine and a model of the slices produced that allow us to view the interior of the skull. (Picture, courtesy of University Medical Center, Department of Radiology, Lubbock, Texas)

Fig. 6.11. This is a simplified version of the process but satisfactory in so much as you don't need to know the details of how it works to interpret a CT scan.

The images can be acquired and presented slice by slice (axial technique) from which the CAT scan got its name: ***c***omputerized ***a***xial ***t***omography. In modern CT machines the image is acquired volumetrically (helical technique) and then can be presented as slices or three-dimensional image or a region of interest such as the blood vessels can be isolated to make a 3D CT angiogram.

When this book was first written X-ray films were most common. However, in many centers, this has been replaced by digital image presentation so that each slice is examined in detail on a computer screen and the non-specialist can also modify the brightness, contrast, size, window level and so on, of the images. The principles highlighted in this book are

FIGURE 6.11 A brain CT scan is produced slice by slice and can also be reconstituted into a three-dimensional image

introductory but should give you enough confidence and method to look at a CT scan and take a decisive step on what next, even if that means summoning a specialist urgently!

Answers to the Exercises

Exercise 1

1&4; 2&8; 3&7; 5&12; 6&10; 9&11

Exercise 2

A = Left frontal horn
B = Left sylvian fissure
C = Third ventricle
D = Ambient cistern

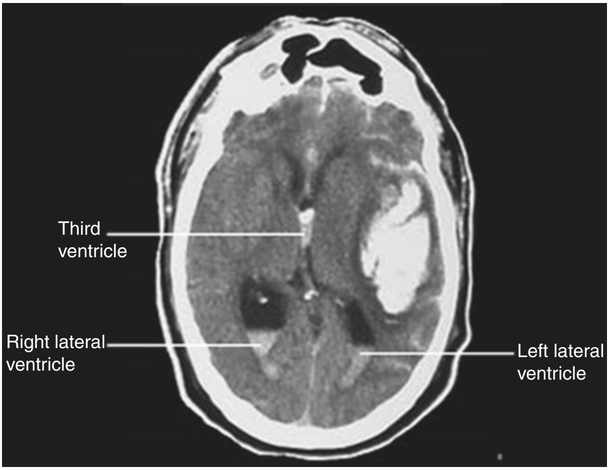
Exercise 3 (any three)

1. Left temporal epidural hematoma with mass effect (compression of the brain)
2. Effacement of the basal cisterns -perimesencephalic cistern
3. Multiple contusions
4. Skull fracture of right temporal bone and left temporal bone

Exercise 4

1. Very severe or irreversible brain damage
2. Because of the attachment of the dura to the sutures
3. The sagittal suture

Exercise 5



1. Left lateral ventricle—occipital horn
2. Right lateral ventricle—occipital horn
3. Third ventricle

Exercise 6

(a) Large right sided acute subdural hematoma (H)
(b) Midline shift- right to left (M)
(c) Subfalcine herniation (F)
(d) Infarction secondary to subfalcine herniation (bounded by the letters I)
(e) Trapped lateral ventricle with dilatation (V)
(f) Subarachnoid hemorrhage on right side (S)
(g) Cochlear implant and resultant artefact (C)

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U. Igbaseimokumo, *Brain CT Scans in Clinical Practice*, In Clinical Practice, https://doi.org/10.1007/978-3-030-14828-7